SECTION 4

Analysis & Recommendations

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Section

4

Analysis and Recommendations

After laying the technical groundwork, the alternative solutions for Nebraska are described and compared and ten major recommendations for Nebraska are presented in detail.

NEVCOM, the Nebraska Virtual Communications System, is at the center of the recommendations offered in this section. **NEVCOM** is a multi-functional and integrated system that fulfills Nebraska's requirements in an innovative and very flexible way. Key technical issues in wireless system design were carefully analyzed and considered as a preliminary to developing the **NEVCOM** system design.

Alternatives were also sought, including the option of retaining existing systems, and making marginal improvements where feasible. A second alternative at the opposite extreme consists of totally converting existing systems to a single new system. This solution would be a good choice functionally, but it is not practical in Nebraska given the large number of fragmented systems and the State's commitment to local autonomy. The third alternative, NEVCOM, requires minimal new capital investment, leverages current investments, provides local autonomy and shared governance, provides interoperability and state-of-the-art functionality, and supports continuous evolution over the long term.

Ten key recommendations are part of the NEVCOM solution, and these are presented in detail later in this Section. Cost and implementation considerations are covered in the following two sections.

Technical Design Issues

Before presenting the technical alternatives for Nebraska, it may be helpful to review some of the general technical design dimensions and their implications. The information below will help orient those who do not regularly deal with wireless communications issues.

Land Mobile vs. Commercial Radio

Many wireless communications technologies co-exist in the marketplace and compete for users. Although similar upon first inspection, these technologies have some important technical, legal and financial differences.

Most public safety radio systems are dedicated systems, known as Private Land Mobile Radio (PLMR) systems. These are owned, leased, and maintained for specific uses by specific licensees, who must be eligible under FCC rules. By contrast, systems that are made available by commercial providers to users who have no particular relationship to each other, include Specialized Mobile Radio (SMR), cellular services, personal communications services (PCS), or satellite-based telephone systems. Public safety agencies make use of these shared commercial systems, in some cases for their primary communications, but more commonly as backup to a dedicated PLMR system.

Private Land Mobile Radio Systems (PLMR)

Public safety PLMR systems are designed for communications of specific scope and purpose. They are dedicated to one or more government agencies whose missions require compatible wireless communications. For example, police, fire, water, and ambulance departments have a natural mutual compatibility because of their similar communications requirements.

Public safety PLMR systems have several distinguishing features:

- Each originating radio is able to broadcast to all other receiving radios (one-to-many). This feature enables the *dispatching* of mobile units from a central location.

- PLMR systems are terrestrial and use frequency bands below 1GHz. Systems in this range offer reasonably satisfactory building penetration (depending upon system engineering) and relative immunity from weather conditions such cloud cover and fog.

- Use of the system is activated using push-to-talk microphones rather than the multiple keystrokes, which are used for telephones.

- Depending upon the system's sophistication, one or more levels of *priority* can permit emergency traffic to commandeer the system at the expense of less important traffic.

- Costs associated with PLMR systems include initial capital acquisition costs plus ongoing maintenance, repair, training, and expansion. Recurring costs are usually minor, such as the lease of antenna space on a third-party tower or building. Licensure is a minor cost.

Commercial Wireless Services.

Commercial wireless providers construct comprehensive radio system infrastructures and lease services to qualifying users. Two variants are Specialized Mobile Radio (SMR) and radiotelephone services.

Specialized Mobile Radio (SMR) is essentially a commercial variant of PLMR.

- Building penetration and immunity to weather conditions are comparable to PLMR systems.

- Dispatch-style one-to-many calling and push-to-talk operation are featured.

- Service is provided on a first-come, first-serve basis. Priority displacement of users for emergency traffic is generally not enabled. Thus public safety agencies using SMR systems must contend for system resources with other subscribers such as taxi companies and local contractors.

- Users bear the cost of their own radios, but do not normally have any direct responsibility for any capital infrastructure costs. Instead, they pay recurring system usage charges, typically on a monthly basis.

Radiotelephone services such as cellular, PCS, and satellite-based systems, are modeled on ordinary telephone systems.

- Radiotelephone services provide dial-up communications with other subscribers on a one-to-one basis. Dispatch mode featuring one-to-many calling is not generally available from commercial service providers.

- Depending upon the infrastructure design, cellular and PCS building penetration may or may not be adequate. With satellite-based systems, heavy weather can be a seriously limiting factor, and in-building operation is seldom effective.

- Multiple keystroke entries (*i.e.*, dialing) are required to access telephone-style systems rather than the simple push-to-talk.

- Access to transmitters is provided on a first-come, first-serve basis. Priority access for specific users is not available at this time.

- As with SMR, users purchase subscriber units and pay monthly recurring charges. Infrastructure costs are born by the service providers.

Comparison of PLMR and Commercial Services.

In recent years, the ubiquity of cellular and PCS services has resulted in public pressure on to replace the PLMR systems used by Federal, state, and local governments. Users of commercial services incur no capital construction costs. Subscribing is simple—a mobile or portable radio is purchased and the agency pays a one-time fee for system initialization and monthly usage fees thereafter.

Commercial alternatives have some serious shortcomings for public safety users.

- Dispatch capability–vital to virtually every public safety operation–is not generally available through commercial services. Dispatchers are an indispensable link between officers and resources or information.

- Push-to-talk operation and one-to-many (broadcast) communications, also essential to public safety operations, are also not available. It is not acceptable to be dialing numbers or making multiple calls for backup while steering an emergency vehicle at high speed. In addition, police and other public safety officials often need for their radios to function while inside buildings.

- Emergencies often require preempting radio channels in the greater interest of life and property. Commercial services virtually never allow preemption.

Thus, the aggregate of experiences of the many public safety agencies that have experimented with commercial services as a substitute for PLMR systems have been largely negative. The lack of functionality significantly outweighs the cost advantages.

In 1999, a three-month demonstration of satellite communications was conducted in central Nebraska by the Federal Highway Administration in cooperation with the Nebraska Department of Roads, the State Patrol, State EMS, and the Norfolk Police Department, and ambulance services and hospitals in Norfolk, Neligh, and Macy. Two satellite vendors' services were tested, and the evaluation was facilitated by the University of Nebraska-Lincoln.

Although positive in some ways, this demonstration did not produce acceptable results for public safety purposes, especially for law enforcement. Communications were clear quality when established, but the service as a whole was subject to interference, message delays, blockages—sometimes the presence of trees was enough to prevent accessing the satellite—and an inability to penetrate buildings. Satellite-based radios need to 'see' the satellite in the open sky, and are therefore 'blinded' upon entering a building.

Within the past few months, however, the State of Florida has concluded an agreement with one of the radio industry leaders for a "partnership" that in some ways resembles commercial service. The Florida system is a public/private system in which the provider owns, implements, and operates the infrastructure. It has bought out the State's inventory of towers and radios. State users purchase their own radios and other terminal equipment and acquire service for a fee from the provider. The State expects that the new agreement will produce substantial savings compared to the constant budget overruns against which it has been struggling in building its own system.

Conventional vs. Trunked Channel Management

A radio system with only one channel funnels all conversations through one portal. Like a movie theater with only one ticket window, users must line up to access the service. Adding more channels (ticket windows) adds more parallel capacity, but individual conventional radio system users must still choose which line to wait in.[1] In any queue, the wait in some lines may be longer than in others. Radio users, unlike people in ticket lines, have no way to know which radio channel queue is the shortest.

Banks and amusement parks sometimes address this problem by creating single, serpentine lines. Queued customers are then automatically send to the next available service window in first-come, first-served order. Voice mail and telephone answering systems also function this way. In a similar manner, trunked radio systems assign available channels to users on a (generally) first-come, first-served basis. Trunked system users have no need (or capability) to review the channels to locate an available one. Instead, the user simply keys the microphone to request a channel assignment, and the system controller automatically does the rest. The system controller issues *call progress tones* to inform the user when to proceed to talk or wait for channel assignment. If all the channels are busy at once, the controller places the channel request in a logical stack for assignment when a channel becomes free. Often, the delay is imperceptible to the user. Thus trunking relieves congestion but does not solve interoperability problems.

Trunking controllers are computers that monitor all ongoing radio traffic and dynamically allocate channels according to pre-defined rules maintained in the system's database. Some trunked systems also have prioritization schemes to allow specified users to 'jump the line' ahead of already-waiting users. This is called *ruthless preemption*, and recognizes that emergency message traffic is considered of greater importance than routine traffic.

Trunking is state-of-the-art for PLMR as well as for cellular, PCS, and ordinary telephone systems. As a result, trunked systems are well-established offerings of major radio equipment manufacturers. There are two primary variants: *transmission trunking* and *message trunking*. Under transmission trunking, the controller assigns a radio channel each time the user keys the microphone to talk. With message trunking, the controller retains the *same* channel for use for the duration of the conversation. Each system has its merits, but they are not always compatible with each other.

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[1] Citizen's Band (CB) radio is a familiar example of a multi-channel radio system. CB users need to agree in advance which of the 40 available channels to select for their communications.

Trunked PLMR systems *register* each mobile and portable subscriber unit (radio). When the radio is powered on, it automatically attempts to contact the nearest trunking repeater, and then transmits its electronic serial number (ESN). The ESN is sent to the trunking controller, which matches it against its database entries. If no match is found, the subscriber unit is presumed to be foreign, *i.e.*, not belonging to the radio system with which it is attempting to register. This discriminatory feature is highly useful to keep intruders out of a trunked system.[2] In addition, radio system manufacturers use different (proprietary) over-the-air data protocols for registration and general operations. A subscriber unit from one manufacturer would not be able to register on a system provided by another, even if the radio frequencies were identical.

The primary advantage of PLMR trunking is the optimal allocation of channel capacity—a scarce resource—on a rational and equitable basis. Fewer channels are required and/or better response times are experienced. In addition, users are prohibited from 'stepping on' other users on the air as they can with conventional systems.

Analog vs. Digital Transmission

Pre-digital (analog) PLMR equipment uses a technique called frequency modulation (FM) to reduce interference. FM changes or modulates the frequencies of the originating signal before it is transmitted, and restores or demodulates it upon reception.[3] This technique was developed during WWII. It was quickly adopted by entertainment, military, and public safety radio systems as a simple and highly effective way to combat atmospheric influences. Today, all analog and digital PLMR systems in use for public safety are FM.

To understand the way this digital augmentation takes place, think of the video images received from distant planets via orbiting satellites. As sent, these images contain missing bits that look like the snow produced by a poor television signal. By using digital compression techniques developed by the cable TV industry, processors replace the missing bits of the image so that the picture we see is complete.

Computer data can be transmitted over FM the same way it is over analog telephone wires: by using modems to convert binary zeroes and ones to tones, transmitting the tones, and reconverting them at the receiving end. The drawback is the need to convert and then restore the information, which imposes a practical upper limit on the attainable data bandwidth and throughput.

The introduction of digital modulation revolutionized PLMR systems. Digital coding offers higher potential computer transmission rates than FM and significantly improves voice and data security as well. Digital signals sound like noise on ordinary analog receivers, and encryption algorithms such as bit inversion, predictor-corrector algorithms, data compression, and other tricks of the digital trade offer further security. Digital encryption also fits more intelligence into a finite channel.

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[2] Conventional (non-trunked) systems have only limited (tone coded squelch) discrimination capability.

[3] FM transmission is accomplished by varying the assigned radio frequency slightly above and below the center position at the audio rate. The receiver circuitry detects these variations and converts them back into sounds through a loudspeaker.

Analog and digital systems also differ in the sound quality they offer at the periphery of their transmission areas. Analog modulation is limited by signal strength and by the thermal noise inherent in electronic circuitry. Analog signals fade with decreasing signal strength and more interference. The farther apart a transmitter and receiver are, the audible information begins to dissolve into white noise. Thus the transmission may still be received but in degraded form until it becomes unintelligible. By contrast, digital signals remain noise-free until the user reaches the farthest edge of the transmission area, where it cuts off abruptly. While still in range, the microprocessors in digital radios track the *bit error rate* of the incoming digital signals and actually fill in the gaps by *predicting* the missing bits and *correcting* for them. This capability results in a slight perceived extension of the *useful* range of a digital system.

Analog radio is like a manual shift in an age of automatic transmissions. Like manual shift cars, analog radios are still plentiful, rugged, reliable, and available in a range of cost and functionality tiers from basic to premium. The vast majority of public safety agencies nationwide still use analog—but most prefer digital because of security considerations. Arguably, new systems should contain at least a digital core in order to be positioned at the leading edge of wireless technologies for the future. Eventually, major manufacturers will almost certainly reduce or discontinue their analog radio product lines, making replacement parts progressively more difficult to obtain.

Wireless Data Considerations

Wireless data transmission actually pre-dates wireless voice transmission by several decades. Morse code—a slow, crude, but highly effective binary data mode—is still used on the short wave radio bands for reliable transfer of information. Morse code turns a transmitter's power off and on in defined patterns that constitute the code. The expression "key the microphone" derives from the Morse code key, the manually operated switch used for making the dots and dashes of the code. The modern manifestation of data transmission, known as *digital modulation* (see discussion above), also relies upon a defined sequence of alternating signal states (ones and zeroes).

Data transmission over PLMR systems is currently a semi-automated process. Digital code is generated by a laptop computer (generally in ubiquitous ASCII[4] characters, which is connected to a data-ready PLMR radio via a serial port. HTML[5]-based software is becoming predominant, as is the TCP/IP[6] protocol, as a result of the deployment of the Internet. In some cases, an Internet browser is usable directly. The laptop has application programs designed to transmit and receive data to and from file servers at a central location.

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[4] American Standard Code for Information Interchange

[5] Hyper Text Markup Language

[6] Transmission Control Protocol/Internet Protocol

When the user presses the <Enter> key on the laptop, the radio transmits a burst of data over the air to the base station. These data bursts occur in the form of *packets*, which are 'check-sum' protected—a technique for detecting and eliminating errors. Received packets having bad check-sums due to interference are re-requested from the originating radio as many times as needed until received correctly. Thus, a high degree of accuracy is inherent in packet data radio schemes.

The system bandwidth required for data communications is proportionate to the volume of data to be transferred. Common experience with the Internet instructs that faster connections (higher bandwidth lines) result in quicker screen changes. With wireless data, the RF link is generally the gating item regulating available bandwidth. The FCC strictly limits radio frequency bandwidths. Data compression techniques create virtual bandwidth by raising effective data throughput. The entire process is intended to be transparent to the user.

Simple but highly useful applications such as license plate lookups and NCIC checks involve filling blanks on the computer screen. Only the *variable* data—not the whole form—is transmitted to the receiving location. Such applications thus require little bandwidth, and can be effective at data rates as low as 300 baud. By contrast, fingerprints, mug shots, and live action video require significantly higher bandwidths, and the radio system can be a bottleneck. Nationwide, nearly half of all public safety agencies use wireless data of some type.

Implementing mobile data in a state-of-the-art radio system presents specific challenges, some of which are due to the different schemes used by radio manufacturers. In a trunked system, for example, data may be transmitted over channels in the trunk rotation with voice traffic, or over dedicated, non-trunked channels reserved for data only. Both methods have their advocates and supporting rationales.

Frequency Band Selection

The radio frequency (RF) spectrum authorized for public safety mobile radio includes several segments in different frequency bands, as discussed elsewhere in this Plan.

Six allocations are defined:

- 30-5- MHz (VHF low band)
- 150-170 MHz (VHF high band)
- 220 MHz (recently allocated)
- 450-470 MHz (UHF)
- 700 MHz region (recently allocated)
- 800 MHz region

Each segment offers advantages and disadvantages. Selecting the appropriate one is application-specific and involves art as well as science.

First, each frequency band exhibits different propagation characteristics. Propagation simply refers to the way a radio signal radiates or extends around its transmitting point.

All radio signals are waves, which have both *frequency* (how fast they occur in cycles per second or "Hertz") and *length* (the distance between one and the next).

An important principle in propagation is the relationship between frequency and wavelength: the higher the frequency the shorter the wavelength. UHF signals, for example, have shorter wavelengths than VHF signals. The physical length of antennas reflects this relationship. Antennas for 39.9 MHz (VHF low band) are about 70 inches long, while comparable antennas for 800 MHz are only 3 inches long.

Attenuation: the loss of volume during transmission, resulting from to losses due to absorption, reflection, diffusion, scattering, deflection, or dispersion.

A second principle of propagation is that, for any given level of transmitter power[7], longer wavelength signals travel farther. At higher frequencies, the wavelengths become shorter and more of its energy is absorbed or otherwise lost. The relationship between attenuation and distance is not linear. For example, 800 MHz signals are attenuated 25 times more than 150 MHz signals, all other factors being equal. An 800 MHz signal can be completely soaked up by tree leaves—especially long pine needles—because the wavelength is comparable to the length of the leaves.[8] Ground conductivity, which depends upon underground mineral deposits (or lack thereof), also affects propagation. Thus in the sand hills of north central Nebraska, radio signal propagation is less than in the farming areas of the south and east.

During WWII it was discovered that UHF signals seemed to penetrate the hulls of ships under construction and facilitate the work of riveters operating on opposite sides of the hull. In fact, the 450 MHz energy was wrapping around the stern and racing back along the hull on both sides. This was a marked improvement over the 50 MHz systems then in common use in shipyards.

Propagation is also affected by transmission line losses, antenna gain and directionality, foliage losses, receiver sensitivities, and building losses. Shorter wavelengths penetrate buildings better than longer wavelengths. The recognized ability of 450 MHz and 800 MHz signals to penetrate buildings better than low band signals is a critical evaluative element in the selection of frequency band for PLMR systems, and offers a great advantage in highly urbanized areas. Unfortunately, the 25:1 absorption rate for 800 MHz over 150 MHz signals means that 3 to 4 times the number of towers and transmitters are required to achieve the same coverage objectives in open territory.

The relationship between tower height and radio coverage is illustrated in Figure 1. The formula used to generate this chart is r = the square root of 2(h), where r is radius of the coverage area in miles, and h is the height of the antenna on the sup-porting structure.

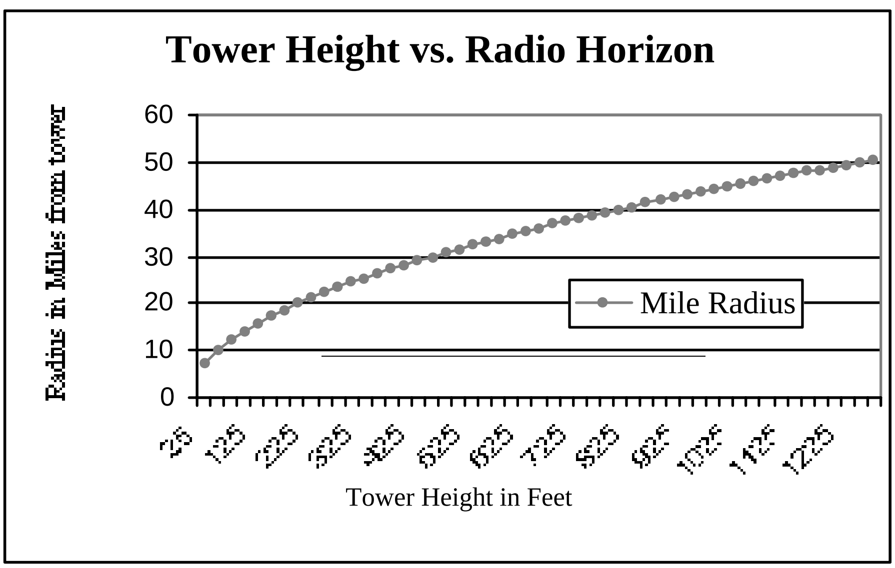

Figure 1: Tower Height vs. RF Horizon

VHF low band (30-50 MHz) suffers from the propagation phenomenon called "skip" and from atmospheric and man-made noise sources. Skip is the importation of unwanted signals from other radio services, sometimes hundreds, and even thousands of miles away. The level of skip is affected by the eleven-year sunspot cycle, which will peak in 2001. At its peak, skip will be at its maximum. Radio hobbyists enjoy this happenstance, but public safety communications can be seriously hindered. Consequently, with the development of the higher frequency bands, low band has fallen into disfavor with both users and manufacturers. Many existing low band systems date back to WWII, some using surplus military equipment. The Federal regulatory agency (FCC) does not even permit trunking below 150 MHz, and little modern low band equipment is currently available.

By contrast, abundant equipment is available for the upper bands, particularly VHF high-band (150 MHz). High band VHF has been extremely popular for decades with both public safety and business users. A considerable range of equipment features and functionality levels, analog and digital, conventional and trunked, wide-, and narrowband, inexpensive to premium priced, are available from numerous manufacturers. Interoperability among manufacturers' designs is almost universal. To a somewhat lesser extent, all of the same comments also apply to equipment made for the 450 MHz band.

Equipment for the 800 MHz band, on the other hand, tends to be manufacturer-specific and relatively expensive. Interoperability is limited to the analog FM modulation mode. The digital implementations use proprietary over-the-air formats and are decidedly *not* compatible. Implementing an 800 MHz system is generally a winner-takes-all proposition for the winning vendor.

In the early 1990s, multiple industry associations endorsed a technical standard, which has become known as *Project 25*. The intention of developing this standard was to facilitate interoperability, maximize the efficient use of the radio spectrum, and support advanced functionality and ease of use. Project 25 systems would be largely trunked using frequencies from 100 to 1000 MHz—which includes VHF high band, UHF, and 700/800 MHz. With a universal over-the-air protocol, it is also intended that multiple competitive manufacturers can build mutually compatible products. To date, however, only one major manufacturer has offered viable Project 25 products, although there have been some recent product announcements from smaller companies. Significant agencies of the Federal government use Project 25 equipment, with most federal applications using VHF high band.

In Nebraska, each frequency band has its advocates and detractors as well. A selection of comments from surveys and interviews from around the state illustrates this point, and the last comment wraps it up:

- "Low band is very reliable."
- "We're happy with our new VHF system."

- "VHF has better coverage than 800 MHz."
- "UHF has been very successful here."
- "We want an 800 MHz system."
- "The State needs a 1-GHz system with central dispatching."
- "The problem is too many frequencies!"

System Capacity and Usage Factors

The number of channels required in a radio system is probabilistically determined using applied statistics and an estimate of the expected average and peak traffic volumes. Queuing theory, derived from the science of Operations Research, is used in the system design process. Three variables are considered: the way users attempt to access the system, the way the system handles access requests, and the way users react to system busies. Two main formulas used: Erlang B and Poisson. The Erlang B formula assumes all blocked calls disappear, never to return. The Poisson distribution assumes no blocked calls ever disappear completely. Instead, it models the probabilities of the three ways callers react when they encounter blockages: (immediate re-try, wait before re-try, or remain on hold). The Poisson distribution can overestimate the number of channels required, while Erlang B formulas is more likely to underestimate them.

In practice, these lofty statistical approaches reduce to a rule-of-thumb of about 100 subscriber units per channel for PLMR systems used by public safety agencies. This number is also enshrined in law: FCC Rules and Regulations (CFR 47, section 90.631) impose loading requirements of 100 units per channel for 800 MHz channels (it can revoke licenses for channels when loading falls below 70 units).

Thus the first step in estimating total system channels is to determine the number of mobiles and portables currently in use and projected, divided by 100. Extra channels are then added for mobile data if it is to be on separate channels from the voice traffic. Some systems also use dedicated channels exclusively for supervision and control.

With caution, channels may be loaded beyond the 100-user rule. Depending on how heavily they actually use their radios, more users per channel can result in longer wait times for channel assignment. During peak traffic times, waits can seem interminable when multiple agencies make heavy use of an undersized system. Mobile data capability can create 'virtual capacity' by off-loading busy voice channels when, for example, police perform their own license plate lookups rather than requesting that service from dispatchers. However, this is not always the case; many users have found that adding mobile data makes them more productive, but does not reduce voice traffic. Trunked systems can take advantage of talk groups to maximize channel loading, since not all agencies require the same channel capacity. The artful design of talk groups can limit some agencies to a subset of the system, making other channels free for higher-priority traffic.

System Integration Issues

Historically, public safety radio systems came into existence in response to the demand for improvements in efficiency and productivity offered by mobile communications. In police work, communications with headquarters and from car-to-car is enormously beneficial to criminal apprehension and to ensuring the safety of life and property. Police forces were pioneers in PLMR sixty years ago, quickly followed by fire services, ambulances, and the other public safety agencies. American urban areas were considerably smaller then, and their governments tended to view themselves as isolated entities. Early PLMR systems were designed and installed to address the perceived needs of the era.

With passing time, the megalopolis emerged. Urban areas sprawled and suburbs blossomed, consuming farmland and creating the need for broader public safety services for a burgeoning post-WWII population. The need for operational cooperation among public safety agencies gradually dawned on public officials, but well after many PLMR systems already existed. The designs of those systems disregarded any interoperation considerations. Technical parameters such as frequency bands, tower heights, coverage areas, and power levels were selected to satisfy only immediate needs. Whether or not two neighboring police departments or fire districts could talk to each other was not considered.

In the present era, the desirability of interoperability among public safety agencies is acknowledged. However, the thousands of legacy PLMR systems—expensively acquired and having many years of service life remaining—pose a serious technical challenge to achieving interoperability. Many agencies throughout the country accomplish functional interoperability by placing telephone calls between dispatchers to relay information from field officers, and by monitoring their counterpart's radio transmissions using scanners. During joint operations, some swap portable radios for use as required. But talking directly across radio system boundaries is a tough nut, seldom cracked.

In short, today's public safety community requires a high degree of inter-agency cooperation and communications interoperability. Even within a given town, area, or region, interoperability problems exist among cooperative agencies within the same jurisdiction. Fire, police, and ambulance services often operate systems on different frequencies. In many cases, dispatchers can "patch" audio between systems, providing a rudimentary degree of interoperability, but manual patching is a cumbersome manual process. Practical alternatives for achieving connectivity among disparate systems range from this primitive patching through consoles through wholesale replacement with entirely new unified systems.

In addition, technical consolidation of radio systems is only one aspect of integration. Nebraska has already experienced many of the benefits of consolidated, area-wide, independent communications centers. This concept is not new or unique to Nebraska. Dispatching of emergency and public services is almost completely centralized in some states. However, central control may or may not be the best arrangement for a given jurisdiction depending on many factors.

Communications networking experience in other areas—voice, computer, and video networks—has benefited in general from the notion of system-level integration or a 'systems approach'. The term system in this context is broadly defined to include all the elements that must operate together to produce the desired results. This definition includes not only equipment and technical elements but also strategic plans, operating policies and procedures, decision-making, change management, staffing, and contract management. From a systems approach, there is no single 'right' answer to what these elements are or how they are put together. What *is* required is that they all be part of a dynamic whole. In fact, functional systems integration can occur even without merging all the physical systems involved.

The key to technical integration is the creation of interfaces among the component technical systems, using to the greatest possible extent standardized or widely accepted common interfacing technology and methods. A clear advantage to standards-based integration is that the individual component parts can develop and change under separate management and on different timelines without disrupting the system as a whole.

Examples of consolidated dispatch centers—such as the ones in Seward, Taylor, Ogallala, Omaha, and other counties in Nebraska—are integrated systems in that the communications centers incorporate or serve the needs of multiple jurisdictions which still have their own separate radio systems. They also have their own operational and management processes that do not disrupt those of the jurisdictions they serve. In Omaha, for example, the Police Department, Sheriff's Department, and other public safety agencies are now considering options for upgrading their individual radio systems. They may decide to consolidate these systems or not, but in either case the planning and coordination at the joint board level can continue to ensure that the whole system functions together.

Assessment of Alternatives

Three major strategic directions the State can take toward improving public safety wireless communications are discussed below. These strategies all arise directly from the current systems and future requirements found in this study.[9]

Review of Nebraska's Concerns and Requirements

Lack of Interoperability. Regular and reliable inter-agency interoperability is urgently needed in Nebraska. Certain agencies such as Douglas County and the Department of Roads have largely self-contained operations and thus relatively less need for interoperability. However, all local and state public safety agencies are significantly hindered by their inability to interconnect. When specific events such as the scenarios described in Section 3 occur, many different agencies may be involved. In these cases, radio systems that can talk to each other are crucial to the safety of citizens and officials.

Fragmentation. Because of an historical lack of statewide coordination, planning, and growth management, current individual radio systems around the state are a collage of every conceivable type and manufacturer. Further diversity is introduced by a mixture of conventional and trunked systems, simplex and duplex systems, private and commercial systems, and digital and analog systems. Few systems are capable of directly intercommunicating. Even users of systems that seem similar, such as the 800 MHz trunked systems in Lancaster and Sarpy counties, find it difficult to communicate due to different underlying technologies and protocols.

Technical Shortfalls. The technical adequacy of current radio systems is also a widespread concern. In many areas of the state, notably the rolling areas of the eastern border, central hills, and panhandle, coverage as low as 60% appears to be common.[10] Lack of coverage can result from many factors, but it is clear that more tower and transmitter sites would be needed to adequately serve even the current requirements for voice radio usage. Other technical inadequacies that affect various agencies include channel capacity, reliability and redundancy, interference, and equipment obsolescence.

Lack of technical sufficiency and functional equity across the state is not aligned with the vision of a "Nebraska United":

> Our mission is to serve ALL Nebraskans. —Governor Johanns

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[9] Other strategies that are theoretically possible, including widespread use of alternative commercial services, have been ruled out for Nebraska based on the discovery process in this study.

Area and Statewide Gaps. Wireless communications systems may serve local, area, regional or statewide levels. *In Nebraska, the most serious and widespread gaps in radio system capabilities are at the area and statewide levels.*

- Local systems serve one or a few local agencies. Examples range from a single, standalone police or sheriff's department radio system to a wireless system used by several public safety agencies in a county. These standalone systems, as noted elsewhere, generally function acceptably for internal use.

- Regional systems serve larger physical territories, corresponding to statewide districting plans. The most widely recognized public safety district plan is the six-region scheme used by the Nebraska State Patrol. Because each agency's radio systems have been developed along their own district lines, regional communications are generally supported.

- Area systems are self-defined countywide or multi-county consolidated systems that serve all or most of the covered public safety agencies.[11] These self-defined areas have arisen from a growing awareness of the benefits of asset sharing or consolidated dispatch. Area systems centered in Ogallala and Taylor (Region 26) are well established. Several other counties such as Seward, Sarpy, Lancaster, and others (see map in Section 2) are still growing or in the planning stages. Successful area cooperation involves working out technical and governance issues as well as agreeing on training and operating procedures. Despite these hurdles, agencies that have made the transition are enthusiastic about the benefits of consolidation.

- Statewide systems provide border-to-border interconnectivity. Currently, *Nebraska has no truly statewide system*. Low band mutual aid channels were originally intended to become statewide. As implemented, they provide the primary system for many sheriff's departments and a number of other public safety agencies,[12] but do not provide direct, contiguous radio contact across the state and are at best a regional system.

Uneven Development. Individual systems also differ in their level of technical development, and these levels parallel the distinctions among territories:

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[10] These reports are based on the professional judgment of the agencies involved. It is difficult to determine whether a given denied attempt is due to system congestion or lack of signal coverage.

[11] Recall that consolidation may be at one of several levels as well, as discussed in Section 3.

[12] In some cases, such as rural volunteer fire and rescue vehicles, low band is the only available frequency.

- Basic voice communications systems tend to be standalone analog, simplex, and low band; many of these systems are functionally obsolete or simply old and worn out. The base stations and repeaters in Brown County, for example, date from the 1950s.

- Enhanced basic voice wireless systems are the next level of development/ Along with basic voice communications these involve some sharing among two or more agencies or the use of different/additional frequency bands.

- Consolidated wireless systems, a third level of development, incorporate newer equipment, at least partial deployment of advanced features such as mobile data, and well-developed interagency coordination.

- Integrated wireless systems are at the fourth level, and include consolidated dispatch with state-of the-art consoles, repeaters for portable-to-portable communications, wide deployment of mobile data, and use of other features such automatic vehicle location and encryption.

Public safety is for everybody. We need a way to share the cost of the radio system so each individual agency could afford it…

For example, the Bedford fire department had a 129 square mile fire. Their annual budget for maintenance of everything is only $2,700. That's less than the cost of one average portable radio…If you need to choose between buying a hundred feet of hose or paying for a year's use of one radio on a system, you know where you're going to put the money.

Costs and Funding. At the same time, a number of individual local radio systems in Nebraska are of recent vintage and incorporate advanced technologies. These newer systems provide good to excellent internal and routine communications, and they represent a substantial financial investment.[13] This level of investment has serious implications:

- Agencies with well-maintained or newer systems and advanced technology deployment are understandably unwilling to bear the cost or disruption involved in changing or replacing these systems.

- At the other end of the spectrum are the very small agencies and those located in sparsely populated, low tax-base areas. Although these agencies are often the most in need of system upgrades or replacement, they are the least able to pay for new equipment.

- State agencies involved in law enforcement (NSP, Game & Parks, DCS, and the State Fire Marshal) are special cases. These state agencies rely both on the current low band system (for either primary internal communications or regional communications) and on a variety of piecemeal solutions to interconnect with local and area systems with which they overlap.

"We have a have and have-not situation. There's no way people in sparsely-populated counties can afford this [enhanced radio system] any more than they could afford telephones or electricity back when.

Radio has got to be viewed as a utility—those folks shouldn't be left behind…

—Alan Curtis, Director
Crime Commission

[13] An estimate of the expenditures by all agencies statewide for new and upgraded radio systems is not available. It is known, for example that Buffalo County/Kearney recently installed four state-of-the-art dispatch positions at a cost of $425,000. Sarpy County has invested $4,500,000 in its consolidated radio and dispatch systems, not including mobile and portable radios.

Funding *and funding equity* are the common denominator issues among these concerns. Agencies in the western parts of the state are concerned that the high-population areas will dominate the design of the solution and absorb the lion's share of any available funding. Agencies with outdated equipment or minimally functioning systems worry that their needs for basic communications will be neglected in favor of adding enhanced functionality elsewhere.

Any proposed solution for Nebraska must in some way meet the following requirements:

- Accommodate many different systems and users

1. Statewide roaming
2. Statewide location
3. Universal interconnectivity
4. Subscriber to subscriber communications

- Be affordable overall and leverage current investments

5. User autonomy
6. 90%/95% Mobile radio coverage
7. 95% Channel availability
8. No single point of failure
9. Voice security available

- Position agencies to meet future technical and capacity requirements

10. Planned growth
11. 100% Wireless data capability
12. Advanced security options
13. Upgrade path

- Facilitate and encourage sharing and coordination

14. Phased installation
15. Universal training

- Support a smooth implementation and migration plan

16. Ease of use
17. Standard procedures
18. Area consolidation
19. Shared governance

The following discussions of Nebraska's three alternatives include implications for infrastructure development, equipment, functions and operations, management and staffing, and costs.

- Infrastructure development means the common elements of a system shared by all users, such as towers, transmitters, antennas, controllers, and interconnecting links.

- Equipment means elements specific to an individual user or agency, such as base stations, consoles, and individual mobile and portable radios.

- Functions and operations cover the capabilities of the system and any specific characteristics of how the systems perform.

- Management and staffing includes management, policies and procedures, maintenance, and training.

- Costs are discussed in a general way in this section; estimated costs for the three alternatives are explained in Section 5 of this Plan.

Alternative 1: Retain Existing Systems with Minimal Enhancement

This "baseline" solution would retain all the systems described in this Plan, including both local and state agency systems. Local systems would continue to develop independently. State and local agencies would continue to rely on low band for minimal regional interoperability among users that had access to low band radios.

Incremental changes could be made to ameliorate some coverage gaps and to accommodate limited growth. The drawing below illustrates graphically the level of improvement that could be expected from such enhancements. The light blue triangles represent the existing regional low band capability, and the irregular shapes represent the spectrum of individual and area systems, which operate on various frequencies. Feasible enhancements, such as leasing or constructing additional towers, or obtaining and equipping additional low band channels, are represented by the darker blue regional triangles.

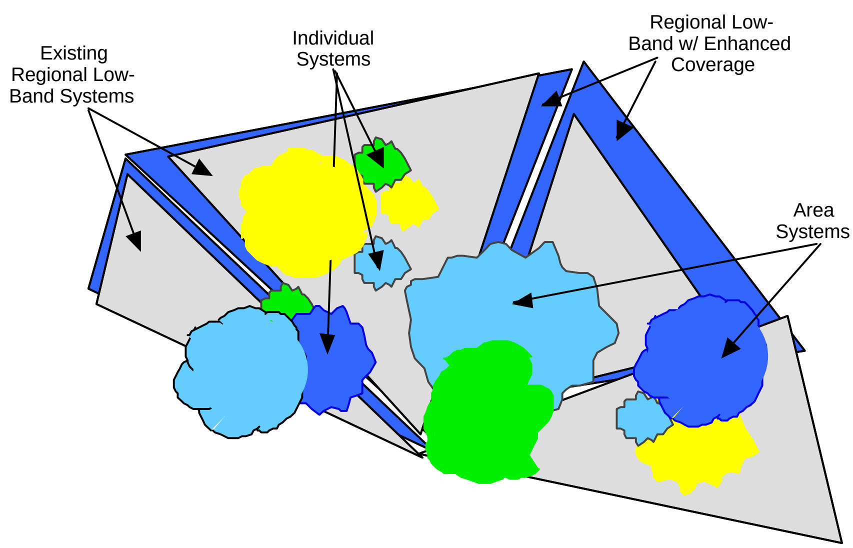

Figure 2: Existing Systems and Alternative 1

Infrastructure Implications of Alternative 1: In order to deal with basic coverage gaps caused by geographical and other factors, additional tower sites and low band transmitters would be required. The total number and location of such sites cannot be calculated based on current data but needed improvements could require a 25% or more increase in facilities for the State Patrol alone.[14] Additional sites would also be needed for local agencies using low band, and none of these additions would enhance the functionality for agencies using other frequency bands such as Game and Parks.

Capacity shortages, unlike coverage gaps, would not be improved by simply adding towers and transmitters. However, in the short term, if local agencies continue to migrate away from low band, capacity for remaining users could improve. Additional low band frequencies would also be available, at least for regional deployment, and would require the purchase of additional base stations and repeaters. Local agencies would need to continue to carry low band radios in order to communicate with the State Patrol and others. Capacity shortages at the local level would need to be addressed on a case-by-case basis.

There is no statewide low band backbone connecting transmitter sites around the state. Communications links connect dispatch consoles for state agencies, but other integrated system functions such as routing, switching, and end-to-end connectivity are not available today.

Equipment Implications of Alternative 1: Minimal. State agencies using low band would need additional base and user (subscriber) equipment only to replace worn out radios or to supply additional users. Local agencies would add or change equipment at their own option. Among local agencies, it is likely that the migration away from low band would continue to occur, resulting in continued investments in fragmented systems.

Functional & Operational Characteristics of Alternative 1: The state will continue to lack statewide interoperability if the current systems are retained.

Existing low band systems are simplex. This means that communications are limited to one talking path between a user and the base station. When a user or base station is talking, the channel is completely unavailable to other users. Simplex systems do not support statewide mobile-to-mobile communications, and they require talk-around frequencies for portable-to-portable communications. The system could be upgraded to repeat mode (duplex), but this would be difficult and expensive relative to the benefits obtained.

[14] State Patrol informally estimates its coverage at 90%+ in much of the state, but this has not been substantiated and it is known that there are areas with coverage gaps. Often, gaps tend to occur in the less populated areas of the state where deploying additional towers is more difficult.

The low band system cannot be upgraded to digital, cannot be trunked, and cannot support end-to-end encryption. Mobile data could be theoretically deployed, but as a practical matter there is not enough RF on the ground for the level of reliability that would be needed. Low band systems are subject to frequent skip[15] and atmospheric interference. This can and does cause problems for voice communications, but users can often make out a voice message despite noise and missed words. Computers, however, effectively lose their ability to function under these conditions. Mobile data deployment would require building a parallel infrastructure at the level of upgrade mentioned earlier.

Management and Staffing Implications of Alternative 1: Minimal.

Cost Implications of Alternative 1: Retaining existing low band systems, even with extensive upgrades, is a low cost alternative. State agencies would probably need additional funding for repairs and maintenance, which has been lacking for many users. Local agencies would experience higher costs to keep their low band systems functioning. In addition, local agencies that have held off making improvements in their own systems would now be faced with a major funding decision.

Alternative 2: Mandatory Total Conversion

This true statewide solution would deploy an entirely new land mobile radio system with all elements in a single frequency band. All individual systems in the state would be required to convert to the new system. Statewide deployment could only be ensured through a state mandate. One of several alternative frequency bands could be selected, although the most likely choices for technical, financial and practical reasons would be VHF or 800 MHz.[16] The drawing at the left illustrates the picture presented by this alternative. The ring around the outside represents the new statewide radio system that would be created. The inner ring represents all the separate, individual systems, now on many frequency bands, which would be incorporated into the new statewide system.

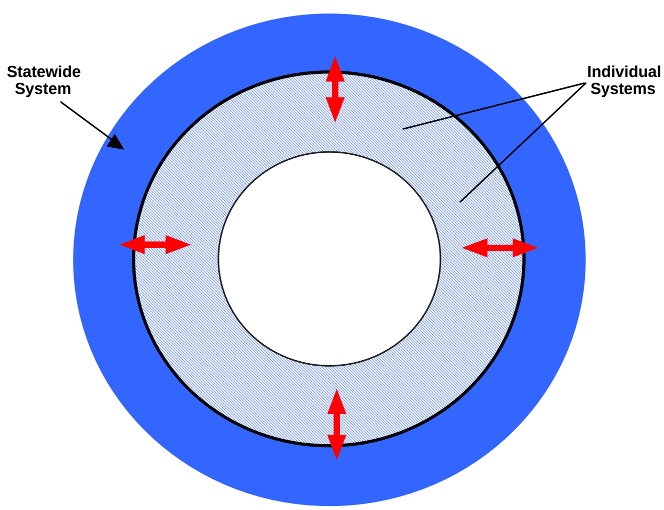

Figure 3: Mandatory Total Conversion

[15] Skip is the appearance of unwanted, distant signals of other users, often from hundreds of miles away.

[16] These two frequency bands are compared in detail elsewhere this Plan.

Infrastructure Implications of Alternative 2: This solution would incorporate state-of-the-art technology, would be trunked statewide, and if VHF (high-band) would be narrowband. Additional tower sites would be needed across the state, and the number and locations of these would depend on the frequency band selected. A backbone would interconnect parts of the system. This backbone would be high capacity and computer controlled to support region-to-region interoperability, data applications, and roaming location.

Equipment Implications of Alternative 2: Wholesale replacement of subscriber equipment not already working on the selected frequency band would be required, including mobiles, portables, and common equipment. Some equipment already on the selected frequency band would require replacement as well to be compatible[17] with the new system. Many, but not all, existing dispatch consoles would be reusable.

Functional & Operational Characteristics of Alternative 2: Given comprehensive deployment and adequate capacity, this alternative would be operationally ideal. Interoperability would be universal, mobile-to-mobile and portable-to-portable communications would be available, and all advanced features and functions could be supported, either initially or when required.

Management and Staffing Implications of Alternative 2: Implementation of this magnitude would need to occur over an extended period. During this time, multiple systems and temporary procedures and many transitional technical steps would be required. The number of technicians required to install, test, and operate systems would be significant. Training needed would be substantial, since this alternative essentially involves the entire public safety spectrum. In addition, a new management structure—plus possibly creation of a new department or division—might be needed to fully support coordinated and unified operations.

Cost Implications of Alternative 2: Alternative 2 would incur the highest costs by a significant margin of the three alternatives presented in this Section. Factors that would most substantially affect the actual costs include:

- Required usage and channel capacity, including projected growth;
- The frequency band selected and thus the number of additional towers needed; and
- Whether the same signal coverage would be deployed uniformly in all areas of the state.

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[17] Older wideband analog would not be compatible with narrowband and potentially digital infrastructure; not all existing 800 MHz systems are interoperable either, as discussed elsewhere.

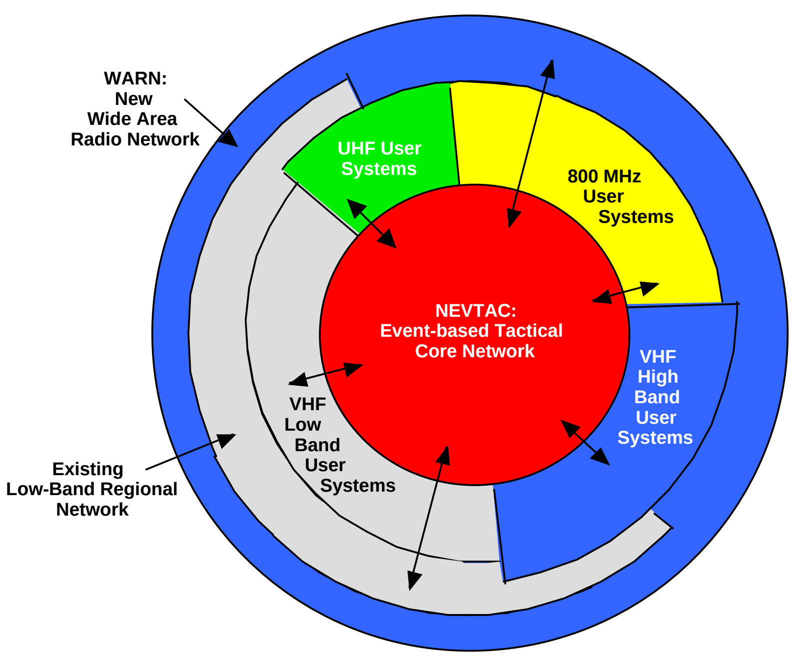
Alternative 3: Nebraska Virtual Communications System (NEVCOM)

NEVCOM would provide a multi-layered, multi-functional solution to Nebraska's requirements, comparable in effect to Alternative 2. In effect the NEVCOM concept views all the public safety wireless communications systems in the state as an inter-related whole. Within this model are both existing radio systems and new systems, tied together by new connections among systems and a shared governance model. **NEVCOM** can be implemented in a number of different ways. It would achieve the same functionality as Alternative 2, but through a combination of related elements: WARN, NEVTAC, and a network of integrated area system interfaces.

Figure 4 illustrates the inter-related nature of these elements. The outer ring represents the new statewide radio system, ***WARN***, just as in the drawing for Alternative 2. The inside ring again represents individual agency systems, but in the **NEVCOM** model, they can retain their autonomy. At the core is ***NEVTAC***, which is interfaced with all other elements and provides tactical interconnection upon demand.

Element 1: WARN

A new system named the Wide Area Radio Network (***WARN***) would be created. ***WARN*** would be similar to Alternative 2 but smaller in scale. Expansion could occur over time to include any desired number of additional users. The Alternative 2 discussion about frequency band selection applies to ***WARN*** as well.[18]



Element 2: NEVTAC

Supplementing ***WARN*** would be an EVent-based, TActical Core network (***NEVTAC***). NEVTAC would inter-connect public safety agencies which are incompatible. However, since such interconnections are only needed at specific times and for specific purposes, ***NEVTAC*** 'virtual networks' would arise as needed using existing local and ***WARN*** capabilities, and would drop when the event was concluded. All ***WARN*** users and potentially all other public safety agencies in the state could participate in ***NEVTAC***.

Figure 4: Alternative 3: NEVCOM

[18] In addition, the existing low band mutual aid channels could be retained as a regional and area ***WARN*** backup, as well as continuing to support agencies using low band as their primary frequency.

Element 3: Individual System Interfaces. Local agencies could retain their current individual and area radio systems, could interface those systems with ***NEVTAC*** at the area or regional levels (or both), or could choose to migrate to ***WARN***. Interfaces would be available at a range of levels that would minimize the cost of local participation.

Infrastructure Implications of Alternative 3: **NEVCOM** implementation would create a series of hubs at appropriate locations around the state, linked by a robust backbone. These hubs would perform (1) switching, control and registration functions for the new statewide radio system, ***WARN***, (2) switching and control functions associated with establishing event-based "networks," and (3) interfacing ***NEVTAC*** to area systems via leased landline connections. The common **NEVCOM** infrastructure would be integrated and centrally serviced. However, it would not need to be owned by the state but could be leased from commercial vendors.

WARN would require infrastructure implementation similar in type to Alternative 2; that is, new tower site equipment and intelligent controllers. Initially, however, ***WARN*** would serve far fewer users, so expansion costs could be phased in as needed. As with Alternative 2, any public safety frequency band could be selected, but VHF and 800 MHz are the feasible choices. Similarly, tower additions and locations would depend on the frequency band selected. ***WARN*** would be data-capable, so that mobile data implementation could be carried out when users are ready. Data aggregation and routing would take place at the **NEVCOM** hubs.

If the **NEVCOM** concept were considered as a set of functional requirements, it might also lend itself to a potential public/private partnership arrangement of the sort recently concluded by the State of Florida. In this case, the infrastructure would not be owned by the State. Note, however, that accomplishing statewide connectivity and coverage implies infrastructure improvements and these must be paid for regardless of whether the State or a provider owns the infrastructure. Thus the costs for either form of ownership might be expected in Nebraska's case to be very close.

Equipment Implications of Alternative 3: Individual systems that choose to transition to ***WARN***, including state law enforcement functions, would require new mobile and portable radios. Reuse of existing radios would be minimal, but much of the State's consoles and other dispatch center equipment could be reused.

Individual systems not transitioning (or postponing transitioning) to ***WARN*** would not be required to change out their radios. They would continue to operate as they do at present. Transport links (and associated electronics) would be required to connect individual systems with ***NEVTAC***.

Functional & Operational Characteristics of Alternative 3: **NEVCOM** as a whole would fulfill Nebraska's requirements for:

- Statewide interoperability on demand (through **NEVTAC**),
- Reliable, state-of-the-art regional communications (through **WARN**), including trunking, mobile-to-mobile and mobile-to-portable communications, optional digital encryption, and so forth.
- A substantial upgrade for current low band users who migrate to **WARN**, and
- The benefits of retaining existing local systems that already function well, and

Management and Staffing Implications of Alternative 3: **NEVCOM** would create an initially *less* extensive technical staffing requirement than Alternative 2, and would require the same or somewhat *more* extensive initial training. Both Alternatives 2 and **NEVCOM** represent major changes for all public safety agencies, so the implementation and coordination requirements would be extensive.

On an ongoing basis, coordination would be an important ingredient of success. Staffing implications for statewide management would be streamlined to a statewide coordinating board and a modest incremental central staffing complement. Staffing impacts on individual agencies would be minimal, however.

Cost Implications of Alternative 3: **NEVCOM** offers significantly lower costs overall compared to the full statewide conversion in Alternative 2, and the actual final cost would depend on the same factors.[19] Costs would be split between the statewide part of **NEVCOM**, ***WARN***, which would initially be much less than the Alternative 2 build-out cost, and ***NEVTAC***, where funding would be directed toward flexible, leased, virtual statewide connectivity. At the same time, impacts on local and individual systems would minimized by requiring only a portion of the costs associated with interfacing with ***NEVTAC***.

Comparison of Alternatives

The discussion below is a structured comparison of the advantages and disadvantages associated with each of three alternatives presented above.

Analysis of Alternative 1: Retain Existing Systems

Benefits and Opportunities

- Least investment for state agencies and least total investment, since only marginal changes would be made.

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[19] These factors are (1) usage and channel capacity including projected growth; (2) frequency band selected, which affects the number of tower sites needed; and (3) whether the same signal coverage would be deployed uniformly in all areas of the state.

- Least investment in new training (although additional training and development of standard procedures are still needed).
- Effective low band utilization would improve as more local agencies migrate to their own systems.

Limitations and Deficiencies

- Does not fulfill the pressing statewide requirements for interoperability and robust, state-of-the-art technology that led to this study.
- Furthermore, statewide fragmentation would become more widespread as local users continued to develop their own systems with no central plan. Agencies with statewide missions would be particularly hampered in this environment.
- Very little new low band equipment is currently on the market, and the range of equipment is limited.
- Interference and skip would continue, at least for several years during the current sunspot cycle. Without significant upgrades, effective mobile-to-mobile communications would still not be possible. Mobile data and other advanced features would not be supported.
- Public safety vehicles would continue to need multiple radios to achieve any level of interoperability.
- Theoretically, one substitute for true interoperability would be for every vehicle to be equipped with radios operating on every frequency.[20] As a practical matter, this would be a very expensive and clumsy solution if implemented universally.

Conclusion

Alternative 1 makes little or no inroads on the highest priority requirements in the wireless community. It leaves state agencies to rely on systems that are at or nearing obsolescence. The cost-benefit ratio for upgrading to even partially fulfill identified requirements is low.

Analysis of Alternative 2: Total Conversion to New System

Benefits and Opportunities

[20] Adding or trading radios among agencies with a frequent need to interoperate is the primary or only form of "interoperability" now available.

- Excellent functional solution.

- Maximum interoperability; the only remaining interoperability issues would be with surrounding states and/or federal agencies.

Limitations and Deficiencies

- High cost. Only existing towers and a fraction of existing equipment could be reused; everything else would be replaced.

- A state mandate (and possibly full state funding) would be required to ensure compliance. Local agencies with new, advanced systems would resist strongly, while smaller jurisdictions would probably not be able to afford the new equipment.

- Significant existing financial investments by local agencies would be abandoned.

- Ability to obtain adequate VHF high-band frequencies is doubtful at least in the short term. NPSPAC frequencies are apparently available, but 800 MHz is the most expensive frequency band to deploy due to propagation characteristics of higher frequency transmissions.

- Loss of redundancy due to a single, monolithic architecture. Adding redundancy to this architecture would be possible but costly.

Conclusion

- This unified statewide system offers excellent technical and functional benefits. As a strategy for Nebraska, however, it faces severe barriers including very high capital costs, a large abandoned investment, widespread resistance to a universal mandate, a long and difficult transition period,[21] and uncertain ability to immediately assemble adequate channel capacity.

<u>Analysis of Alternative 3: NEVCOM</u>

Benefits and Opportunities

- **NEVCOM**'s multi-layered approach leverages individual agencies' extensive investments in current radio technology. No state-mandated

[21] One of the longest transitions for a similar system is in Ohio, where the consulting study comparable to this Plan was performed in 1987 and the network will not be completed even for state agencies until 2003.

changes are required—each local agency would be free to choose when to participate and at what level of interconnectivity.

- **NEVCOM** provides a flexible way to accomplish a high level of area, regional and statewide interoperability. In addition, it supports equivalent opportunities across all parts of the state.

- It provides a high level of redundancy.

- Initial implementation is less extensive than Alternative 2. Major problems such as interoperability and upgrade of obsolete systems can be solved right away, and full implementation can be phased in a number of ways.

- **NEVCOM** provides flexibility to accommodate growth, evolving technologies, and changing regulations without requiring wholesale changes or replacements. The elements of **NEVCOM** can evolve independently while still maintaining the integrity of the system as a whole.

- The **NEVCOM** concept lends itself to either a State ownership or some form of creative partnership with a radio supplier.

Limitations and Deficiencies

- The benefits of total, statewide, uniform implementation would not be available unless or until all individual systems were participating. It is important to understand that ***WARN*** and ***NEVTAC*** become more valuable to all their users as more agencies join the system. Thus a strong commitment to encouraging growth is required to achieve full benefits.

- Multiple radios in some vehicles would continue to be required for some time, since conversion would not be uniform.

- Somewhat more complex procedures and training would need to be developed initially. (This does not imply that the systems would not be user friendly, only that the transition would require a substantial effort.)

Conclusion

- **NEVCOM** is a practical solution for Nebraska's particularly complex environment. Through its three interconnected layers, it fulfills the requirements identified in this study and aligns with Governor

Johanns' "Nebraska United" vision, while optimizing costs and benefits.

Figure 5 on the next page summarizes these advantages and disadvantages in a convenient chart. It appears that **NEVCOM** offers the best solution for Nebraska of the available alternatives. Following the summary chart, the Recommendations section explores the NEVCOM alternative in detail.

	Alternative 1: Retain Existing Systems and Use Low band for Interoperability	Alternative 2: Mandated Conversion to Single Frequency Band; Discard All Current Systems	Alternative 3: **NEVCOM**: Add ***NEVTAC*** and ***WARN***, Retain Most Local Systems; Retain Low band
Equipment	Equipment only for upgrades or growth.	Nearly total replacement of all equipment even if new.	Replacement of much of current low band and some other equipment; local systems retained.
Infra-structure	Limited optional added tower sites to improve coverage.	Substantial additional tower sites, backbone, repeaters, controllers, etc.	Additional infrastructure and backbone for WARN and NEVTAC.
Functional & Operational	Upgrades will improve low band; overall functionality same as present.	Ideal functional solution.	Three-pronged rather than uniform approach. Functionally close to Alternative 2
Cost & Implemen-tation	Lowest cost; shortest implementation.	Significantly higher cost than other alternatives. State mandate needed. Longest implementation period.	Lower cost than Alternative 2. Initial implementation limited, followed by ongoing gradual migration.
Management & Staffing	Minimal.	Technical and training needed over a long period. Potential new management requirements.	Initial technical and training extensive. Statewide coordination essential.
Maps to Require-ments	Marginal improvement; does not fulfill identified requirements or accommodate further evolution.	Meets and potentially exceeds identified and future requirements.	Adequately fulfills identified requirements, solves major concerns, provides long-range flexibility.

Figure 5: Comparison of Alternatives

Study Recommendations

*The major underlying recommendation arising from this study is the adoption of the **NEVCOM** model and the orderly implementation of its elements.*

A number of specific technical and non-technical recommendations are associated with the **NEVCOM** concept. These are presented in detail below. Cost and implementation aspects of **NEVCOM** appear later in Sections 5 and 6, respectively. Note that NEVCOM-related equipment and services would be provided from the private sector. Section 6 recommends a prime contractor/systems integrator approach to procurement in order to maximize performance levels.

The ten key NEVCOM recommendations that follow are:

1. Implement Wide Area Radio Network (WARN)
2. Create Event-based Tactical Network (NEVTAC)
3. Develop Local Area Interfaces
4. Enhance Low Band Mutual-Aid System
5. Create NEVCOM Shared Governance Board
6. Expand DOC Management and Staffing
7. Establish NEVCOM Grant Program
8. Develop Uniform Procedures and Protocols
9. Outsource NEVCOM Implementation Assistance
10. Develop Life Cycle Funding Approach

1. Implement Wide Area Radio Network (WARN)

WARN is a new, state-of-the-art radio system that will provide statewide, regional, and area connectivity and other much-needed functionality to public safety users. It will replace primary radio systems for specific state and local users initially, but will have the long-term growth potential to support all users. Below, the important design parameters for WARN are discussed:

1.1 Frequency Band
1.2 Tower Sites
1.3 Backbone and Hubs
1.4 Functional Capabilities
1.5 Initial Users
1.6 Long-Term Development

1.1 WARN Frequency Band.

One of two feasible frequency bands must be selected for ***WARN***: VHF (high band) or 800 MHz.[22] Both offer state-of-the-art functionality and are well developed and supported in the marketplace.

- VHF High Band. The technical advantages of VHF are discussed elsewhere in this Plan. A key cost-related advantage is that VHF calls for fewer tower sites than 800 MHz to achieve the same level of coverage. This difference is explored more fully below. A second cost-related issue is the wider range of equipment available for VHF systems. Both fully featured and relatively inexpensive utility VHF radios are available to fulfill different needs and budget constraints. In addition, as will be discussed later in Section 5, the state may be able to take advantage of federal VHF asset sharing programs.

  Sufficient VHF frequencies are available for ***WARN*** initial implementation and subsequent growth. This study included a full frequency search for narrowband VHF frequencies in Nebraska and the surrounding states. The results of this frequency search are briefly summarized in Figure 6 on the next page. More detailed summaries are in an Appendix and the full data reports are in an Attachment to this Plan.

- 800 MHz (NPSPAC). Among the advantages of 800 MHz is the availability of frequencies under the State's NPSPAC Plan. Only a few of the channels identified in this plan have been utilized by local agencies to date. Sufficient total channels are available within the allocation to support all Nebraska's public safety needs for the foreseeable future. Because the NPSPAC Plan is very complete and detailed, and has been accepted by the FCC, it was not necessary to perform further frequency searches to investigate 800 MHz for this study.

  800 MHz is also free from most kinds of man-made and natural interference. Thus it can provide good in-building penetration, which makes it a frequent choice for urban systems such as the one in Lincoln. However, 800 MHz systems are highly vendor-specific, so

[22] As noted in Section 2, the FCC has also allocated new frequencies in the 700 band, and in the past two months has issued a band plan governing the use of these frequencies. However, although this allocation is a valuable resource for the future, especially in parts of the country where frequencies are crowded, it will be some years yet before equipment is widely deployed in this band. In addition, Nebraska has sufficient availability in the 800 MHz band, in which equipment availability is good.

systems from different manufacturers may not be fully compatible. Selecting 800 MHz thus essentially ties the State to a single vendor.

In Figure 6, "Clear" means the frequency was unlicensed on the search date, and "Possible" means the frequency may be available even though currently licensed to another governmental entity. Forty total frequencies are identified.

Frequency	North East	North Central	North West	South East	South Central	South West
151.0325	Clear	Clear	Clear	Clear	Clear	Clear
151.1675	Clear	Clear	Clear	Clear	Clear	Clear
151.2425	Clear	Clear	Clear	Clear	Clear	Possible
151.3625	Clear	Clear	Possible	Clear	Clear	Clear
151.4075	Clear	Clear	Possible	Clear	Clear	Clear
153.7475	Possible	Clear	Possible	Possible	Possible	Possible
153.8075	Possible	Possible	Possible	Possible	Possible	Clear
153.8975	Possible	Clear	Possible	Possible	Possible	Possible
153.9425	Clear	Clear	Possible	Possible	Clear	Possible
154.0025	Possible	Clear	Clear	Possible	Possible	Clear
154.0175	Clear	Clear	Possible	Possible	Possible	Clear
154.2275	Possible	Clear	Possible	Possible	Clear	Clear
154.3025	Possible	Clear	Clear	Possible	Clear	Possible
154.3475	Possible	Clear	Clear	Possible	Clear	Possible
154.4375	Possible	Clear	Possible	Possible	Clear	Possible
154.6875	Clear	Clear	Clear	Clear	Clear	Possible
154.7925	Possible	Clear	Possible	Clear	Possible	Clear
154.8375	Possible	Clear	Clear	Possible	Clear	Clear
154.9425	Possible	Clear	Clear	Possible	Clear	Clear
155.0025	Possible	Possible	Possible	Possible	Possible	Clear
155.0775	Possible	Possible	Clear	Clear	Clear	Possible
155.3175	Possible	Clear	Clear	Possible	Clear	Clear
155.4375	Possible	Clear	Clear	Clear	Possible	Clear
155.5275	Possible	Clear	Possible	Clear	Possible	Clear
155.5875	Clear	Clear	Clear	Possible	Possible	Possible
155.6325	Possible	Possible	Clear	Possible	Clear	Possible
155.9325	Possible	Possible	Possible	Possible	Possible	Possible
155.9925	Possible	Clear	Possible	Possible	Possible	Clear
156.0075	Possible	Clear	Possible	Possible	Clear	Clear
156.0975	Clear	Clear	Clear	Possible	Possible	Possible
156.1275	Clear	Clear	Clear	Clear	Possible	Possible
156.2175	Possible	Clear	Clear	Possible	Possible	Possible
158.9925	Possible	Possible	Clear	Possible	Clear	Possible
159.0075	Clear	Clear	Clear	Possible	Clear	Possible
159.2325	Clear	Clear	Clear	Clear	Clear	Clear
159.2775	Clear	Clear	Clear	Clear	Clear	Clear
159.3075	Clear	Clear	Possible	Clear	Clear	Clear
159.3525	Clear	Clear	Possible	Clear	Clear	Possible
159.3825	Clear	Clear	Possible	Clear	Clear	Possible
159.4425	Clear	Clear	Clear	Clear	Clear	Possible

Total Clear	18	34	22	17	25	19

Figure 6: Nebraska Frequency Search Results Summary

Determining the frequency band for ***WARN*** at the earliest possible date would be beneficial, since another applicant may license the potentially available VHF frequencies discovered in this study at any time. NPSPAC frequencies are also reserved only through the year 2000 under the current plan. The State may choose to solicit proposals for the system without specifying the frequency band to be used. In this case, it should be noted that the marketplace at the present time is unlikely to voluntarily respond with anything other than an 800 MHz solution.

1.2 Radio Tower Sites.

WARN will be deployed throughout the state, with transmitters on multiple towers so as to provide the required levels of coverage Since different frequencies propagate in different patterns, the selection of the frequency band will determine what tower sites and transmitter locations are required for coverage.

The towers currently used by state agencies were summarized in Section 2 of this Plan. Most are owned by one of four state agencies, but some are leased from public or private owners. Additional potential tower sites may be available from public power districts, local governments, or telecommunications carriers.

This study included a technical analysis of coverage that could be expected for ***WARN*** assuming either a VHF or an 800 MHz implementation. This study made the following assumptions for both alternatives:

Reuse of towers currently owned or occupied by a state agency.[23]

Mobile unit transmitter power	35.0 Watts
Base station receiver sensitivity	0.5 µVolts
Mobile unit antenna gain (quarter wave whip)	0.0 dB

System use factor[24]

• VHF	-4.0 dB
• 800 MHz	-6.0 dB

[23] Where there were two or more existing towers, those owned by the State or 299' in height or more were selected.

[24] General system loss factor applied to cover signal degradation due to variations in mobile unit antenna placement, vehicular ignition, ambient RF noise, and general maintenance degradation. Coverage predictions as plotted in this study have a loss factor of about –6.0 dB built in to cover variations in terrain elevation, foliage density, and normal atmospheric fading.

Base receiver for VHF:

• Transmission line loss (7/8" Heliax @ 160 MHz)	-0.5 dB/100 ft.
• Antenna system gain (multicoupler and filters)	+1.5 dB
• Antenna gain (DB Products DB-224)	+6.0 dB

Base receiver for 800 MHz:

• Transmission line loss (7/8" Heliax @ 800 MHz)	-0.9 dB/100 ft.
• Antenna system gain (multicoupler and filters)	+4.5 dB
• Antenna gain (DB Products DB-806)	+6.0 dB

Calculated net system gain/loss

• VHF system	+1.9 dB
• 800 MHz system	+1.6 dB

Nominal talk-back coverage radius	VHF	800 MHz
• From a 300' tower	29.5 miles	16.0 miles
• From a 200' tower	26.0 miles	11.3 miles
• From a 150' tower	23.5 miles	7.5 miles

Coverage from Existing Towers

Figures 7 and 8 on the next two pages show the coverage that could be expected from these configurations. Specifically, the coverage areas shown on these two maps represent the following percentages:

Total Area of Nebraska	77,358 sq. mi.	100%
VHF Coverage	Area Covered	% of Nebraska
• 52 Existing Towers	67,718 sq. mi.	88%
• Coverage Voids	9,640 sq. mi.	12%
800 Coverage		
• 52 Existing Towers	35,150 sq. mi.	45%
• Coverage Voids	42,547 sq. mi.	55%

Note: These computer-generated maps simulate coverage based on the above assumptions only. They are not detailed propagation models based on full terrain and environmental factors.

Figure 7: 35-Watt Mobile Coverage and Coverage Voids: 160 MHz, Existing Towers

This map shows projected coverage for mobile radios on a new VHF high band WARN system, using 52 existing tower sites.

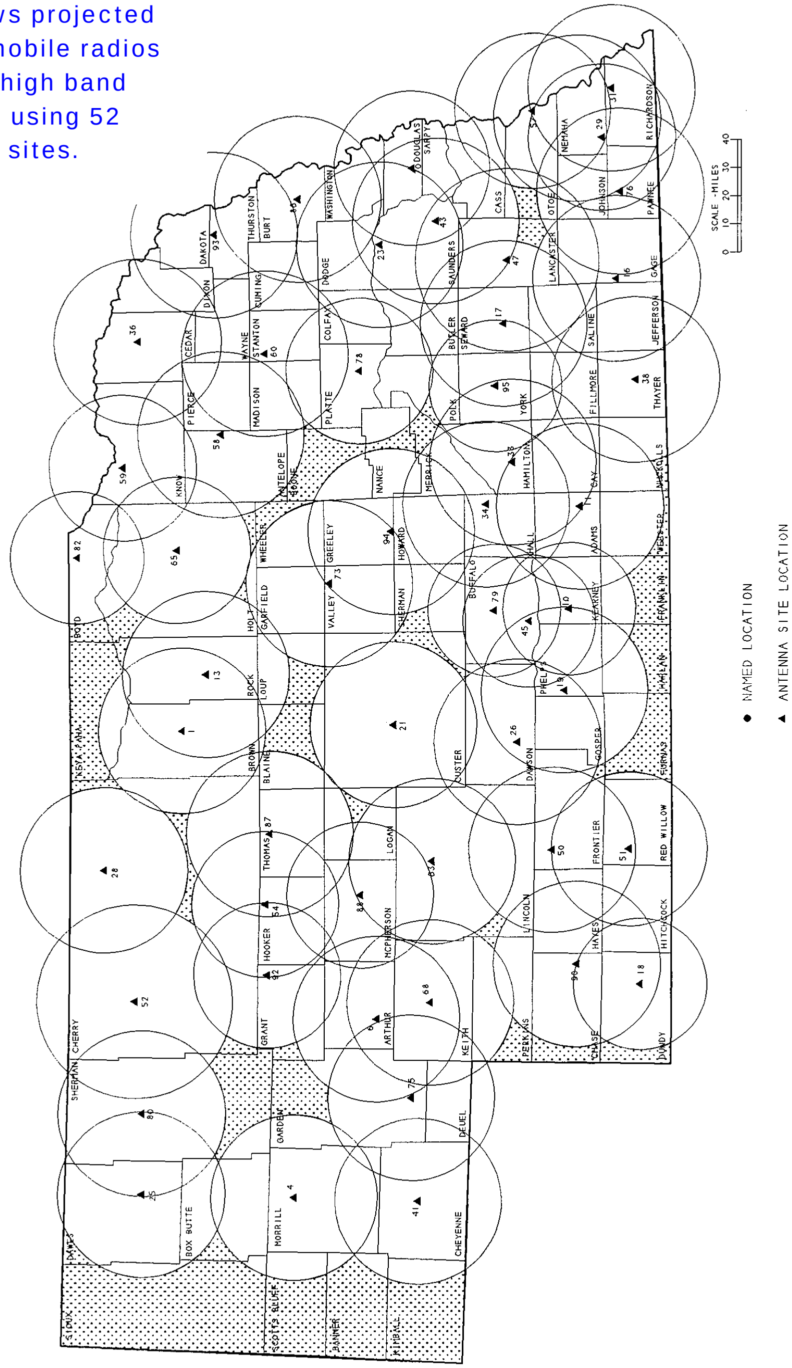
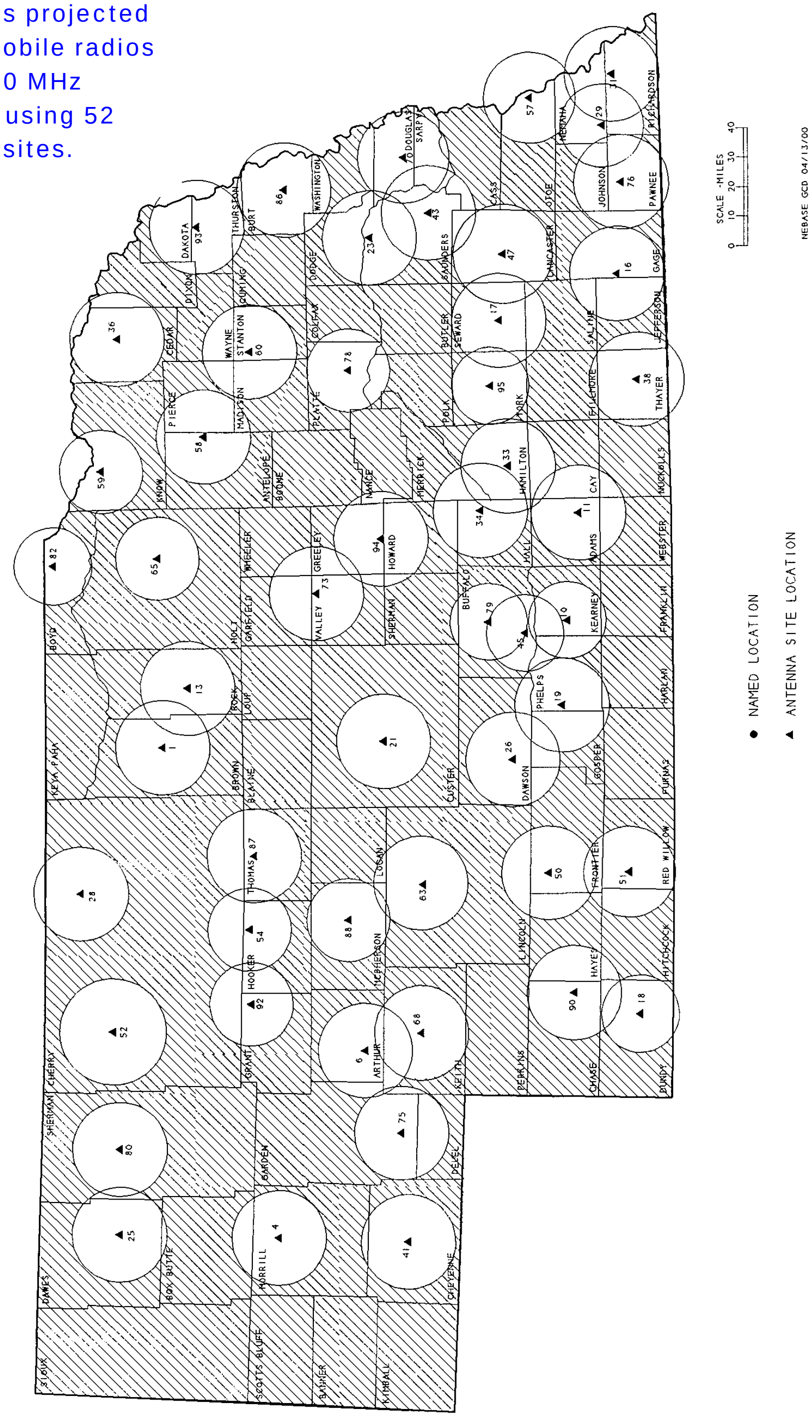


Figure 8: 35-Watt Mobile Coverage and Coverage Voids: 800 MHz, Existing Towers

This map shows projected coverage for mobile radios using a new 800 MHz WARN system, using 52 existing tower sites.



Additional Towers To Improve Coverage

As Figures 7 and 8 show, the coverage using existing towers is greater using VHF than it is for 800 MHz. This is obviously a valid finding, given the relationship between frequency (wavelength) and propagation distance, as discussed earlier in this Section.

Looking at the two maps, clearly VHF comes the closest to providing coverage at the required 90-95% level. A second computer simulation was conducted to learn what would be required to complete the coverage assuming a VHF solution. It was found that this might be accomplished by adding approximately 12 towers in gaps. These locations are shown on the following map and overlay (Figure 5).[25] Keep in mind that detailed coverage calculations and tower siting would be a responsibility of proposers to a State request for proposals, and that the simulations and siting in this report are intended to verify conceptual alternatives and provide a basis for budgetary costing.

VHF Coverage: 64 Towers	76,120 sq. mi.	98%

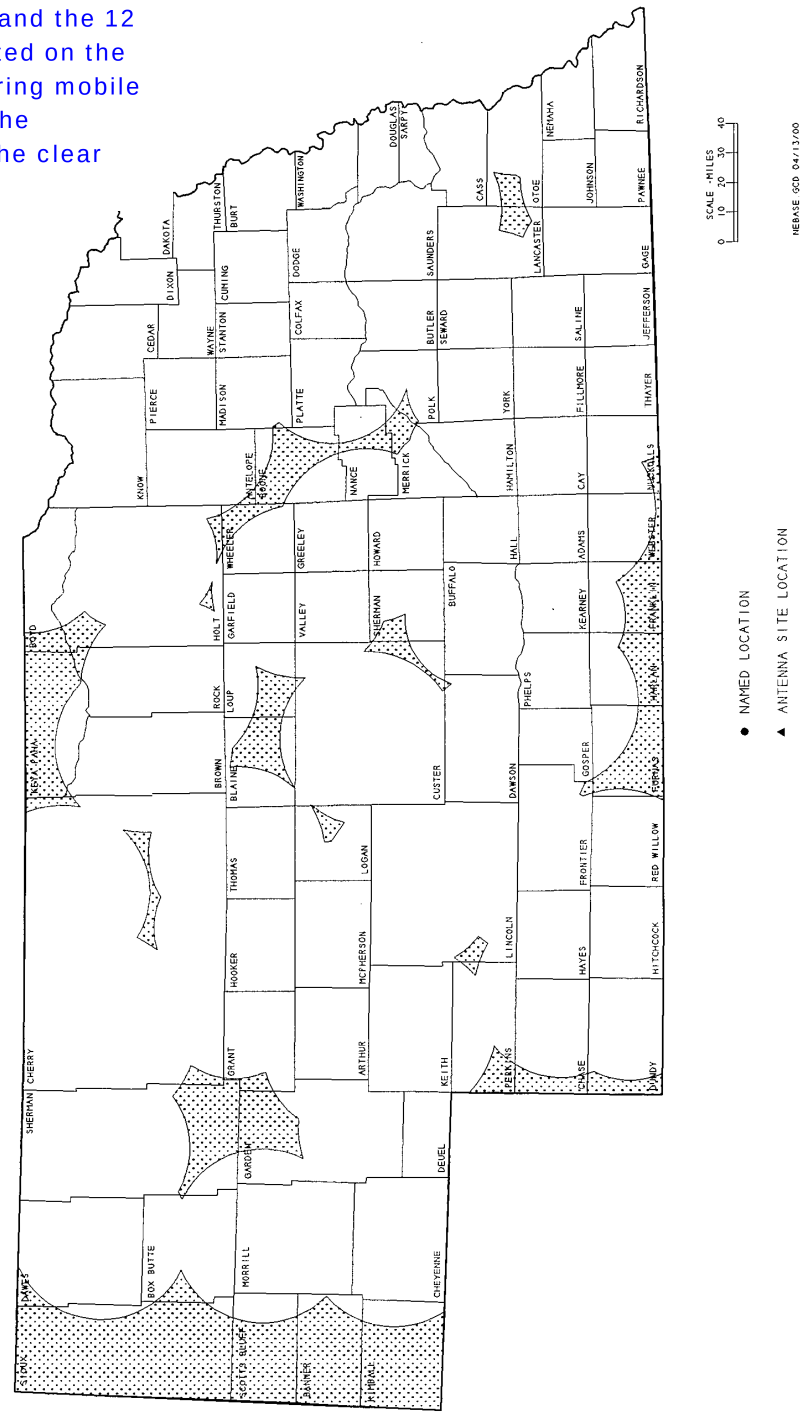
All proposed towers are 300' in height. The additional towers on the overlay are as follows:

Site	Antenna	Approximate Location
A	9.0 dB Offset	7.0 miles NE of Harrison, NE
B	9.0 dB Offset	7.0 miles North of Mitchell, NE
C	9.0 dB Offset	6.5 miles NW of Kimball, NE
D	6.0 dB Omni	6.0 miles East of Lakeside, NE
E	9.0 dB Offset	5.0 miles West of Burton, NE
F	6.0 dB Omni	8.0 miles SE of Brewster, NE
G	6.0 dB Omni	13.0 miles East of Bartlett, NE
H	6.0 dB Omni	3.0 miles South of Mason City, NE
I	6.0 dB Omni	9.0 miles NE of Fullerton, NE
J	9.0 dB Offset	3.0 miles SW of Beaver City, NE
K	9.0 dB Offset	3.0 miles West of Franklin, NE
L	6.0 dB Omni	Close proximity to Bennet, NE

[25] As noted earlier, when all the data are submitted from public power districts and common carriers, some of these proposed sites may be found to already exist and be available for sharing or lease.

Figure 9: VHF (160 MHz) Coverage Showing Existing and Projected Additional Towers

This map shows outlines of the 52 Existing Towers per Figure 7 (in the background), and the 12 additional towers listed on the previous page that bring mobile radio coverage into the specified range (on the clear overlay).



For the 800 MHz alternative, the situation is less promising. The existing towers provide approximately 45% coverage of the state. For the purposes of this study, accurately predicting the number and locations of additional towers required to achieve the desired coverage would be speculative at best and has not been attempted. A simple way of approximating tower site requirements is to use the ratio from the coverage study above: 52 towers: 45% coverage. Based on this calculation, approximately 115 (52/45%) towers will be assumed to be required.

Portable Coverage

Portable coverage is a thorny issue. The majority of the radio users surveyed and interviewed make more or less extensive use of portables on a regular basis. As part of this study, portable coverage simulations were developed making similar assumptions to the mobile communications calculations with the following exceptions:

Portable unit transmitter power	5.0 Watts
Portable unit antenna gain (quarter wave whip)	-8.0 dB

Calculated net system gain/loss

• VHF system	-6.1 dB
• 800 MHz system	-3.4 dB

Nominal talk-back coverage radius	VHF	800 MHz
• From a 300' tower	14.8 miles	9.3 miles
• From a 200' tower	13.0 miles	4.8 miles
• From a 150' tower	11.7 miles	2.4 miles

The maps resulting from these simulations look similar to the mobile coverage maps above, but with smaller coverage areas around each tower site. However, such maps are somewhat visually misleading. Ideally, portable radio coverage "should" parallel mobile coverage in all cases. In reality, due to cost and physical limitations, it is not feasible to set a one-size-fits-all standard for portable coverage. Actual portable coverage requirements vary greatly from agency to agency and application to application.

Police departments, for example, typically need to ensure good in-building portable coverage. A police department implementing WARN as its primary system would undoubtedly supplement the statewide infrastructure with locality-specific transmitters to boost coverage in specific areas. Furthermore, these specific requirements would be determined by careful study at the time of implementation, and could only be guessed at now.

State and local users will need to be judicious in targeting and prioritizing infrastructure enhancements to support portable coverage. Given the great overall improvements offered by ***WARN*** over current capabilities, users should not be overly anxious at the idea of selectively supplementing the system's reach over time. Public safety radio systems in Nebraska have always been incrementally developed as need and funding dictates; with the advent of **NEVCOM**, these incremental developments can now be directed at a common goal and leveraged to the maximum extent possible.

In developing a request for proposals, an area of great importance will be the requirements for portable communications and unit-to-unit communications. The use of vehicular repeaters, currently employed as a work around, is not possible with a trunked radio system. However, proposers should be required to offer a range of solutions to accomplish portable coverage at whatever level is needed for a specific area, agency, or application.

1.3 Backbone Hubs and Interconnecting Links

A backbone and hub locations are required for several reasons:

- To tie the widely-dispersed ***WARN*** transmitter sites together into a functional whole,
- To furnish area and regional communications via the ***WARN*** controllers,
- To support required statewide location and roaming capabilities,
- To provide ***WARN*** users with access to ***NEVTAC*** functionality.

The logical diagram below illustrates this hub and backbone structure. Exact placements of hubs and links will be a subject for detailed design by prospective network vendors. For purposes of cost estimation (see Section 5), DOC suggested six likely hub locations to minimize transport costs.

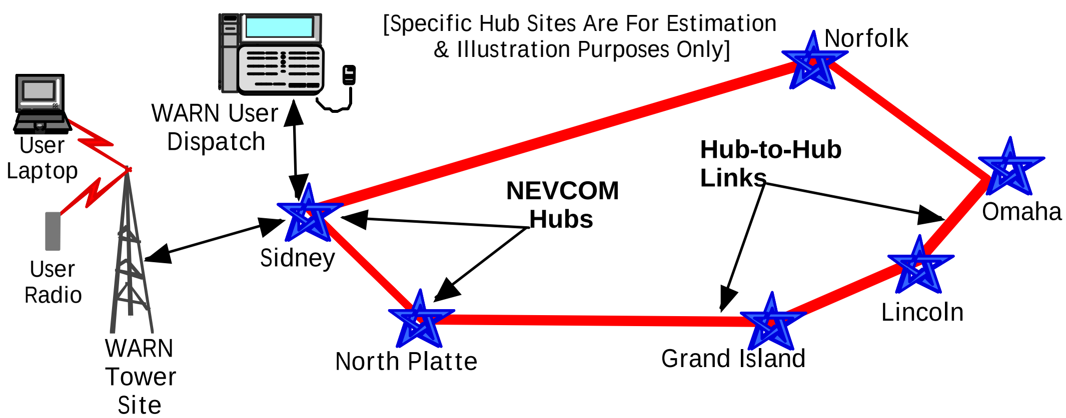


Figure 10: Hub and Backbone Configuration for ***WARN***

It is also assumed that the backbone links will be obtained from telecommunications common carriers, either directly or through a DOC service agreement. Hub design will also be a proposer-specified element; hubs will serve the following functions:

- Interconnection of backbone links
- Interfaces with regional and area systems, individual users, and ***WARN***,
- Switching and routing of voice radio traffic,
- Connection to ***WARN*** radio controllers,

- Automated set up and tear down of ***NEVTAC*** networks.

1.4 WARN Functional Capabilities

In specifying required functions of WARN, the following points should be included:

- Statewide roaming and statewide location. ***WARN*** will be a trunked system statewide. Any user will be registered with the closest tower whenever his or her radio is turned on. The system will track automatically which tower is closest to the user; thus ensuring that the user can access the system and can also be located at any time.

- Subscriber to subscriber communications. Properly designed and implemented, WARN should provide service to both mobile and portable subscriber units. Note coverage details in Appendix G.

- 90-95% (mobile) coverage. See the discussion on tower sites and coverage earlier in this section. Higher coverage rates, while desirable, are not technically or economically feasible, and cannot in any case be guaranteed.[26]

- 95% channel availability. ***WARN*** is envisioned based on user populations as a 1-10 voice channels per site system, with possible growth to 20 total channels (this equates to 40 frequencies since channels use frequency pairs). At least 40 VHF frequencies were discovered in this study, of which 10 are unoccupied in at least 5 regions of the state. Adequate NPSPAC (800 MHz) frequencies are also available. See also the discussion on frequency availability earlier in this section.

"Use of advanced technology services will triple if budgets allow."
—National Institute of Justice, Research Report NCJ 168961

- No single point of failure. ***WARN*** has several ways of ensuring redundancy, including the backbone infrastructure, multiple channels, intelligent controllers, and the continued availability of low band mutual aid frequencies.

- Digital-ready. ***WARN*** will be implemented as an analog system initially, but at the State's direction, the core equipment (repeaters, controllers) will be capable of both digital and analog operation, so that the conversion to digital can occur without wholesale infrastructure replacements.

- Voice security (advanced security options). Modern trunked radio systems are capable of several levels of security, up to and including digital encryption. The

[26] The PSWAB stressed the importance of coverage and recommended "maximum possible WARN coverage."

initial analog implementation of ***WARN*** will provide voice encryption at a minimum.

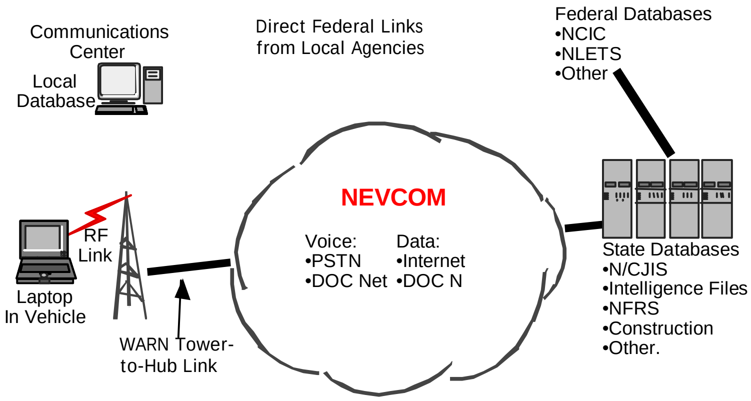


Figure 11: WARN Data Connectivity Possibilities

- <u>100% wireless data capability</u>. WARN will also be capable of supporting data communications from at the time of implementation. Data repeaters will be provided at every site, and many of the user radios will be data-capable.

The figure on the right shows variations in data connectivity for ***WARN*** users. ***WARN*** users who purchase laptops for in-vehicle use will thus be able to reach a hub, where a ***WARN*** controller will 'hand off' the data to the State data network for transport to the server location. Local ***WARN*** users may have direct connections to their own databases as well. Both state and local servers may have access to national databases such as NCIC.

1.5 WARN Initial Users.

Initial implementation of ***WARN*** should include state law enforcement functions, emergency management, and local agencies who are ready and able to join.

State law enforcement in this context includes the following:

- Nebraska State Patrol
- Nebraska Game and Parks Commission, law enforcement employees
- Nebraska State Fire Marshal's Office
- Department of Correctional Services, inmate transport officers
- Nebraska Emergency Management Administration (including outfitting the Mobile Command Post Communications Van with programmable ***WARN*** portable radios.

Note that this list has been developed solely in order to permit development of a phased cost model (in Section 5), and does not in any way imply that other state agencies or divisions or local agencies should not be included or should not migrate to ***WARN***. Also note that agencies who do not participate in ***WARN*** will still be able participate in ***NEVTAC*** for interoperability purposes.

1.6 WARN Long Term Development.

The state should view **NEVCOM** as a long-term investment, and this view should be reflected in management and planning as well as funding strategies.

A key advantage of the **NEVCOM** model is its flexibility to evolve and adapt to future conditions that can be only imperfectly foreseen. Over time **NEVCOM** will be affected by regulatory changes, new and different technologies or product offerings, common carrier service developments, population and crime rate shifts and their effects on public safety agency staffing, and replacements of individual radio systems. These changes may potentially occur in endless combinations and on many different possible schedules.

In one desirable future scenario, for example, as shown here:

•Many additional local and area systems would have migrated onto ***WARN*** as their primary system.

•Low band regional service is still available but much less prevalent.

•NEVTAC continues to support cross-band interoperability.

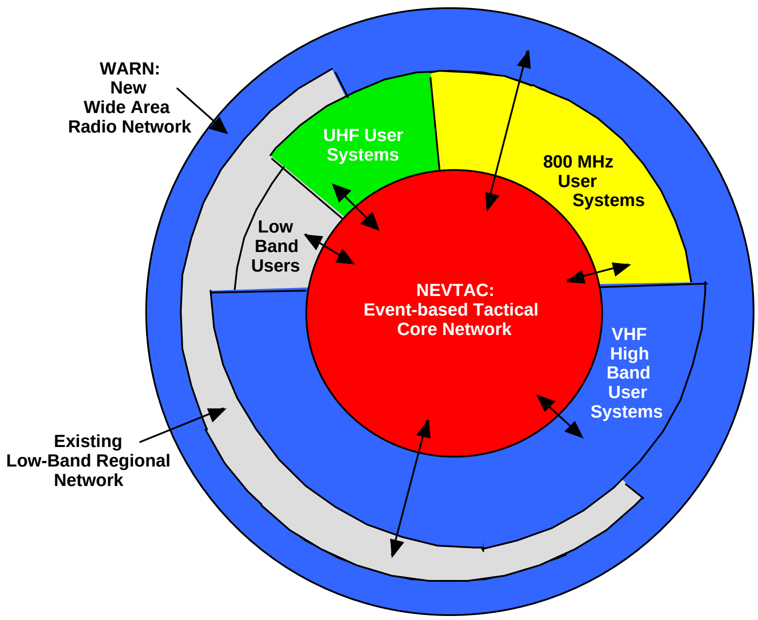


Figure 12: **NEVCOM** Possible Growth Scenario

Growth and Expansion. Growth has two components: (1) increased staff and therefore numbers of individual radio users for ***WARN*** member agencies; and (2) migration of new user agencies to ***WARN***. Channel requirements are currently estimated at up to 10 channels per site. Mobile data deployment, especially if complex applications such as construction drawings or offender 'mugshots' were to come on line, could increase this total capacity. It would be premature to attempt to determine at this point whether mobile data transmission between vehicles and area nodes should be handled in-band with voice traffic or over separate channels.

Replacements and Upgrades. Digital deployment is likely to occur within the design life of ***WARN***, and with it higher levels of security will be possible. Another feature that is almost universally needed, Automated Vehicle Location (AVL), would be another beneficial upgrade to ***WARN***. Other beneficial upgrades at the individual agency level, such as data deployment and computer-aided-dispatch, can be supported by the system.

Benefits of Recommendation 1: ***WARN*** offers modern, state-of-the-art technology to replace current systems in critical need applications where the lack of functionality has seriously hampered law enforcement and other public safety missions.

2. Create Event-based Tactical Network (NEVTAC)

It is recommended that NEVTAC be deployed as quickly as possible to radio systems at all levels throughout the state. The ***NEVTAC*** concept consists of interconnecting existing area and regional repeaters and communications centers at the baseband audio level by means *other* than human (dispatcher) intervention. Conceptually, these interconnections can be triggered almost instantly by state-of-the-art switching and routing equipment that has been pre-programmed for event service in a number of configurations to address a myriad of event scenarios.

Fewer than half of all public safety agencies in the US today can "patch" across channels, and 90% of those must have a dispatcher set up and take down the patch."
—National Institute of Justice, Research Report NCJ 168961

Area (Node) Events and Regional (Hub) Events

In the normal course of day-to-day operations, most Nebraska public safety agencies use just a fraction of their radio systems' total capacity. For the most part, the channels are quiet. From time to time, and especially during emergencies, radio traffic explodes. Depending on the severity of the situation, various combinations of agencies may converge on a scene or need to coordinate their actions. The requirement for these officials to talk among themselves arises immediately. In this study, tactical situations requiring interoperability are called *events*, and the scenarios presented in Section 3 are a balanced sample of such events. Events vary in size, scope, and complexity, and public safety agency responses vary accordingly. So do their interoperable communications requirements.

- Node Events. Areas are the basic functional building block for ***NEVTAC***. An area includes all the local agencies in a cooperating group, and includes a dispatcher or communications center. It can range in size from one local agency to a multi-county group of local agencies such as Region 26. In network terms each area is a node. There is a 1:1:1 relationship among areas:nodes:dispatch locations.

  A node event may be local or areawide. For example, adding a State Fire Marshal's officer to a local arson investigation or a Federal agent to a drug investigation is a local area event confined to a relatively small location. Interoperability is often accomplished today by exchanging portable radios to enable wireless information exchanges during the operation. In some locations, a dispatcher can activate cross-band patching. This manual *patching*[27] is relatively simple to set up if the capability is present and a dispatcher is available. ***NEVTAC*** will add automated local connection capability at the node level.

A larger area event is wider in scope, and draws a combination of local responding entities from nearby locales. Unless those separate locales are jointly served by a consolidated dispatch center, they generally lack the capability to interconnect their radio systems though patching. The Sheriff's frequency (39.9 MHz) may be a useful resource, but unfortunately this channel is also used for paging in many places, interfering with critical voice traffic in the early stages of events. Again, the ***NEVTAC*** capability at the node level will provide the needed interconnection.

- Hub Events. Regions are the second building block for ***NEVTAC***. A regional event involves multiple areas and may involve agencies of the state and Federal governments. The radio communications problems noted under the area discussion above are compounded by an order of magnitude. Today, state agencies are interconnected through their internal regional-scale districts, but they lack direct interoperability with the local and Federal agencies, except again by using 39.9 MHz or trading portable radios among key officials. Statewide events involve more than one region[28]. Statewide (or near-statewide) events in Nebraska are yet another order of magnitude more difficult from the communications perspective

For example, in response to a local event such as a car fire involving a house, the police, sheriff, fire, and EMS radio systems could be immediately inter-connected by action of a responsible official such as the police or fire chief. This trigger action might consist of entering a short keystroke sequence into a microphone equipped with a keypad.

Each respective radio system could be equipped a programmable decoder to detect valid trigger sequences and activate the network accordingly. Different sequences could be developed to cause different sets of inter-connections depending upon the magnitude and particulars of the event underway.

NEVTAC Interconnection Strategies

The many legacy radio systems existing throughout Nebraska at all levels of government represent significant investments over time; and while some are aged, many are still capable of providing years of useful service. It may be reasonably assumed that many of those systems will survive well into the future regardless of the recommendations of any study. The alternative to wholesale replacement is to *knit these systems together into a functional network*.

Dispatch center patching, where available, provides rudimentary interoperability. A system user requests the dispatcher to patch to the other system(s). The dispatcher responds by setting switches on the dispatch console to create the interconnection(s), which persist until a request to break the patch is made. During the period when the systems are patched together, *all* messages regardless of system of origin are re-broadcast on all the systems so interconnected. This kind of

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27 The term "patching" simply means a manual cross-connection. It does not imply a negative ("patched") solution.

28 Region in this context is generic and does not refer to any of the established regions of any particular agency.

patching is most helpful for relatively routine matters. It is limited to agencies that share a dispatcher, so it may not be available when needed in a variety of situations.

For a larger event such as a grass fire or fugitive chase, officials thus need to collaboratively activate larger networks of sub-networks to provide a wider coverage interoperative system for use during the event's progress until conclusion. This is the capability provided by ***NEVTAC***. The network could also be progressively dissolved (sub-network by sub-network) using microphone keypads as described earlier.

The figure below illustrates the various levels of NEVTAC node and hub event-based tactical interconnections.

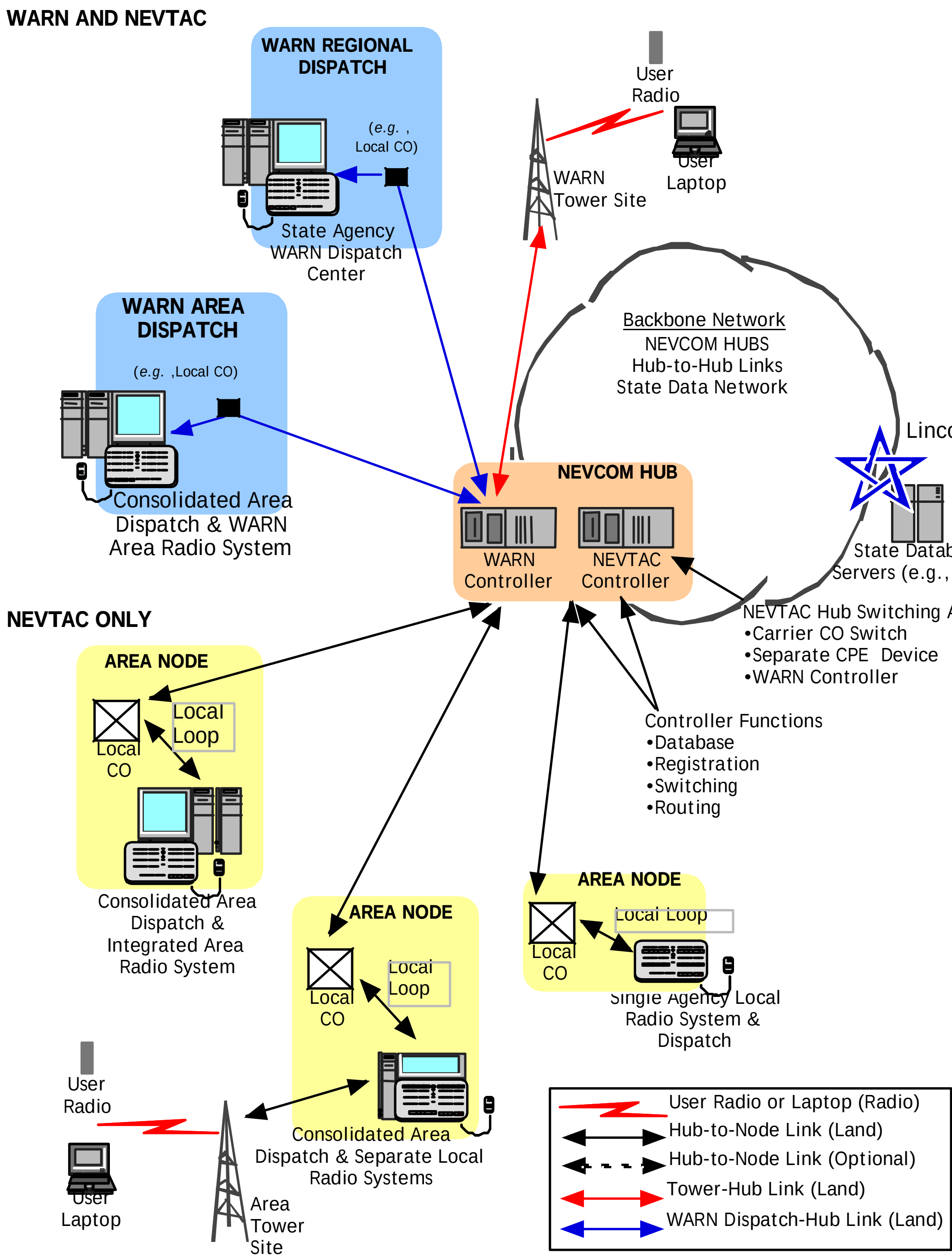

Figure 13: NEVCOM Logical Topology

Benefits of Recommendation 3: ***NEVTAC*** supports the required interconnectivity among disparate radio systems, without requiring replacement of all systems with a new unified system.

3. Develop Local and Area Interfaces

It is recommended that public safety users have a *variety* of ways to interface with ***NEVTAC***. Areas can have different radio technologies, different priorities, and different procedures; critical to the success of ***NEVTAC*** is the working out of inter-jurisdictional agreements that govern the activation of ***NEVTAC*** connections.

Nodes and Hubs. The terms *node* and *hub* were introduced in Figure 15: ***NEVCOM*** Logical Topology. *Nodes* are central connection points for the lowest-level (area) networks. By definition, each area is a ***NEVTAC*** node. *Hubs* are associated with regions; they are connection points to nodes and are the core of star network connections. Co-located with the hubs are the intelligent functions of switching and routing for both ***NEVTAC*** and ***WARN***. Hubs enable the selective interconnection of local sub-networks to achieve inter-area, area-regional and statewide interoperability on demand. A database and associated administrative hardware are assumed to be part of the design. The diagram below illustrates these details.

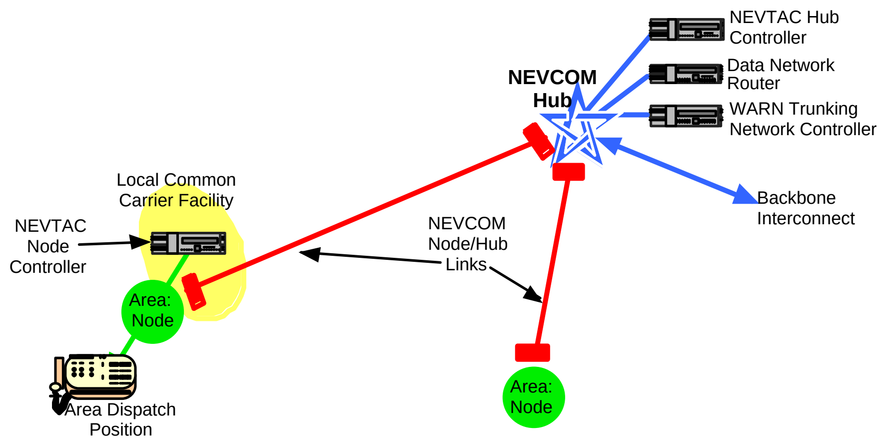

Figure 14: NEVTAC Network Elements

Node Connections. Most base and repeater stations designed by major radio manufacturers possess the optional capability of remote control operation. This is usually accomplished by the installation of an interface card into the station. These cards are available from the manufacturers for recent stations, and from after-market sources for the older equipment.

Three basic signals are involved in remote control operation: transmit/receive control, receive audio, and transmit audio. Older direct current remote control designs use the polarity and magnitude of precise currents to change state from the receive state (default) to the transmit state, and require copper lines. Newer tone remote control designs use precision control tones to switch between states, and can use non-conductive fiber optical lines. Both systems were designed to interface with the telephone network and therefore certain technical parameters such as line levels and impedances are standardized. Standardization provides the basis to construct nodes designed to standard, common interface specifications. The required interfaces may be available off-the-shelf or they could be designed by prospective vendors to Nebraska, based upon the control and switching circuitry found within consoles used to perform patches.

- Node controllers may be used at nodes, but most node NEVTAC events can probably be handled by local exchange telephone companies. Either way, node control consists of switching and audio routing functions between *stations* during an event. Known combinations of stations useful for different event scenarios within each participating area can be made available for activation as “presets”. The logic and addressing to establish the preset network configurations would reside in the node controller.

- Hub controllers would be required at hubs; these may be separate devices or may be handled by WARN controllers. These hubs will perform switching and audio routing functions between *nodes* or between nodes and WARN during an event. Their functions should be controllable by commands sent from a node, the hub controller, or a hub-level radio system. Therefore the logic and addressing to establish inter-nodal configurations would reside in the hub controller. Hubs would be connected in a ring configuration to provide some measure of defense against total system failure.

The small table below compares events that take place within areas or nodes (e.g., between the Seward Police and Sheriff’s Departments), between nodes (e.g., between Seward and Lancaster Counties), and between one or more nodes and regions (e.g., Lancaster County, the State Patrol, and Corrections).

Event Type:	Activated by	Connection Via
Intra-node	Area user	Node
Inter-node	Area user	Hub
Node/Region	Area or regional user	Hub

Again, careful agreements among jurisdictions will be required in order to establish for each agency the conditions under which ***NEVTAC*** activation is appropriate, and to determine the various combinations of agencies that need to be software defined.

Benefits of Recommendation 3: ***NEVTAC*** links and controllers provide equivalent statewide functionality to a single statewide system, offering interconnectivity without loss of autonomy for individual agencies.

4. Enhance Low Band Mutual Aid System

Low band, for all its shortcomings, is in service around the state and used for many purposes, which are described in detail elsewhere in this Plan. The State will need to determine the long-term disposition of low band channels that it licenses and that are licensed for mutual aid.

(1) Area and Regional Uses of Low Band. The State should retain its licenses for VHF low band frequencies and continue to use these frequencies—and continue their use by local entities—as a back-up regional interoperability system.

In any case, during the transition period to ***WARN***, state agencies will need to retain their low band radio access to 39.9, 39.82, and related mutual aid channels. The NSP, which uses low band frequencies in the 40 MHz range, will also need to retain these channels at least until ***WARN*** upgrade is completed for them.

(2) Low Band Augmentation. Since state agencies and many local agencies will continue to use low band either for primary or secondary service, some enhancements should be considered to improve coverage.

The ***WARN*** implementation will result in new installations and additional tower sites. Specifically, additional transmitters should be placed at selected locations where coverage is marginal but where there are primary users of 39.9 MHz. Examples of such areas might include the eastern border counties in the south and north, the southwest corner of the state, and along several northern border areas. The present study did not include propagation research for low band, and this task would properly fall to a prospective vendor.

Benefits of Recommendation 4: Minor enhancements of low band mutual aid capabilities will permit participation in **NEVCOM** by agencies using low band as their primary frequency, and will facilitate interoperability across state boundaries.

5. Create NEVCOM Shared Governance Board

Shared governance among state and local public safety agencies is essential to the success of **NEVCOM**.

(1) Expanded **NEVCOM** Board. It is recommended that the State of Nebraska create a permanent board to replace the Public Safety Wireless Advisory Board

(PSWAB).[29] The new NEVCOM Board would have similar but expanded representation of all public safety users.

(2) Board Roles and Responsibilities. The following would be among the roles and responsibilities assigned to the **NEVCOM** Board:

- Assist the Division of Communications in **NEVCOM** Implementation;
- Develop rules and annual priorities for the **NEVCOM** Grant Program, which is described in Recommendation 7 below.
- Make annual awards under this fund, and report annually to the Legislature regarding the outcomes resulting from the grants;
- Coordinate ongoing public awareness efforts to ensure that local decision-makers are well informed about the benefits and commitments involved in joining ***NEVTAC*** and ***WARN***; and
- Apply for federal grants, coordinate the submission of all public safety federal grant proposals, and review the evaluations submitted to federal funding authorities under established grants.

Benefits of Recommendation 5: By expanding the current PSWAB, making it permanent, and assigning to it shared governance responsibilities for public safety wireless communications, the state will ensure long-term continuity and the fullest possible cooperation within this large and diverse community of interests. Governor Johann's vision for Nebraska United will be supported by this initiative: "Our departments need to team up. Government has built silos that stagnate progress—tear the silos down."

6. Expand DOC Management and Service

NEVCOM implementation and continuing coordination will not require creation of a separate department or addition of a large staff. Nevertheless, critical areas of responsibility will be added with the adoption of this model, including contract management and administration of grants programs and other board activities.

6.1 DOC Roles and Responsibilities. The existing authority of DOC for voice, data, image, and wireless network services should specifically include land mobile radio network services. Additional tasks and responsibilities that are required include:

[29] PSWAB was created by 1999 LB446 to oversee this study.

- Establishing contracts for all wireless services and perform ***NEVTAC/ WARN*** contract management;

- Chairing the **NEVCOM** Board (see recommendation #5) and provide staff support to Board activities;

- Oversee and coordinate **NEVCOM** maintenance and training provision; and

- Administering federal and state public safety communications grants, including the **NEVCOM** Grant Program (See Recommendation 7 below).

6.2 DOC Staffing. To carry out the responsibilities outlined above and to provide service to public safety users statewide, a minimum additional staffing complement of 4.5 FTE positions as noted on the chart below. Note that these are bare-bones minimum staffing requirements for functions that cannot be outsourced. The State should not seriously consider making any significant change to current radio systems without providing these positions.

1.0 FTE	Network Service Manager This position will be primarily responsible for *ongoing* individualized project management for WARN and NEVTAC conversions. Each state and local agency migrating to these networks will require separate consulting services, design of individual systems and interfaces, assistance in developing on-site procedures, oversight of vendor performance, and assurance of coordination between individual agencies and the statewide systems.
1.0 FTE	Grants Coordinator This position will have two related elements: (1) Identify relevant Federal and foundation grant opportunities, cultivate relationships with grants officers, develop grants for state and local agencies, facilitate joint applications, write or assist with writing and submitting proposals, and report as required to granting authorities on the use of funds. (2) Assist the NEVCOM Board in making grants from Federal, foundation and State funds (the NEVCOM Grant Program, Recommendation 7 below), including working with agencies, developing grant materials, reviewing grants for presentation to the Board, administering awards and evaluations, and reporting on the effectiveness of funds to funding sources.

1.0 FTE	Data Administrator Trunked radio systems require all users and all talk groups to be up to date in the network control data base at all times. This activity, called "fleet management," is a full-time responsibility involving regular user liaison as well as management of network records.
1.0 FTE 0.5 FTE	Program Assistant Program Support

Figure 15: Table of Recommended Positions

The Division of Communications currently has 2.0 FTE positions in the radio section. The Radio Manager is responsible for assisting agencies with FCC licensing, administering cellular, PCS and paging contracts, and consulting with agencies regarding improvements in their radio systems. In this the Radio Manager is assisted with billing and customer service by a support position. With the implementation of NEVCOM, the Radio Manager will also take on responsibility for NEVCOM contract management, planning and growth, and ensuring performance by contractors. It will also assume a leadership role on the NEVCOM board, advising on policy and operational issues. These roles are demanding and will preclude taking on any of the responsibilities identified for the new positions.

It is important to understand that almost all of the new workload associated with NEVCOM will be outsourced, both initially and on a continuing basis. No additional state employees are recommended for performing systems integration, management of multiple service and equipment providers, maintenance and repairs, training required for agency radio officers, technicians, users or dispatchers, or IT network management. However, the functions above should not be outsourced:

- Contract administration of other outsourced functions cannot itself be outsourced without compromising the State's ability to enforce performance by the selected contractors. The internal project managers overseeing system implementation and working with users must be State employees, capable of making decisions within their area of authority. In addition, in consulting with local agencies, the network services manager will ensure that users are receiving timely and accurate information from the contractors, and that contractor performance is fully supported and integrated with overall efforts.

- Grants coordination is inherently a State responsibility requiring continuity of relationships and internal processes. Specific assistance can be sought in connection with writing individual grants, but working with the Board and the department to administer state and federal funds and to help set policy and priority goals requires trusted internal staff expertise.

- Data administration is a mission-critical operating function for the State. Ensuring that the constant flow of changes is made accurately can affect life and safety for public safety officers.

It is also not recommended that any of the new functions be allocated outside the Division of Communications, although individual positions could be filled through interagency transfers rather than new positions.

Benefits of Recommendation 6: Minimum state staffing; outsourcing of most new workload to system contractors.

7. Establish NEVCOM Grant Program

It is recommended that an annual State appropriation be made for enhancing and coordinating public safety communications. Grants from this fund would be approved by the **NEVCOM** Board, which would develop the rules under which the program operated. The Division of Communications would provide staff support.

The NEVCOM Grant Fund is the State's opportunity to influence public safety communications policy on a long-term basis. The fund would also make recurring individual funding requests unnecessary by providing the tools for the entire public safety community to become more self-sufficient. Furthermore, the fund would provide a stable source of matching dollars to support federal grant applications.

Suggested priorities for use of funding might include (but not be limited to) the following:

- Equipment and operational support to agencies for which the cost of joining ***NEVTAC*** would pose an undue hardship.

- Fostering area wide cooperation among multiple public safety agencies.

- Augmenting local systems to alleviate critical communications shortages or to add critical functionality.

Priorities for funding grant requests could be established in each fiscal year, and accomplishments made possible by the use of grant funds would be reported annually to the Legislature.

"You could have a lot less congestion if dispatchers had standards of operation…otherwise it doesn't make any difference if we come up with a new statewide frequency, the congestion issues will be the same."
—Pete Peterson, Keith County Communications

Benefits of Recommendation 7: Joint public safety operations are essential to Nebraska lives and safety. This grant fund will encourage local entities to join ***WARN*** and ***NEVTAC*** and facilitate area consolidations. In addition, the fund will raise the quality of public safety communications planning and stimulate more orderly, consistent and phased transitions.

8. Develop Uniform Procedures and Protocols

It would be impossible to overemphasize the importance of standard procedures and operating practices, which have been discussed elsewhere in this Plan. Installing, maintaining and managing the technology proposed above will be to little avail in the absence of good working agreements at the area, regional and statewide levels. The **NEVCOM** Board should take responsibility for working with agencies at all levels to develop model agreements, operating plans and manuals, and facilitating determinations about how and when ***NEVTAC*** connections will be established.

Benefits of Recommendation 8: The initial effort to develop operating agreements and tactical details is substantial, but the payoff will be in effective use of the system by all levels of users.

9. Outsource NEVCOM Implementation Project Management Services

This study leads to conclusions about how to proceed with the planning, design, and implementation of a comprehensive statewide public safety wireless communications system. Overall program management and oversight for this process is the responsibility of the Nebraska Division of Communications, encompassing planning, directing, controlling, supervising and coordination leading to the full realization of the wireless system herein proposed.

It is recommended that DOC contract with an outside source for assistance with system implementation, rather than adding state employees. The timelines for the various work elements are covered in Section 6.

Implementation steps, which will be covered in detail in Section 6, are briefly categorized as follows; the proposed outsourced project manager would assist with any or all of these steps.

- Crafting an RFP to solicit proposals
- Evaluating proposals to the RFP
- Contract negotiations and award
- Implementation project management and contract performance monitoring

Crafting an RFP. The RFP should be developed with specific, detailed knowledge and understanding of the recommendations of this study. The technical, managerial, political and policy ramifications of implementing a statewide public safety wireless system of this scope and magnitude are weighty and deserve a cautious and deliberate undertaking. The RFP should be designed in such a manner as to permit the assignment of weighted numerical point values to vendor responses to aid in the evaluation process. The RFP should contain an outline of an acceptance test plan, which becomes incorporated by reference into the subsequent contract(s).

Evaluating Proposals. A rational, objective scheme should be developed for evaluating vendor responses to the RFP, and the evaluation process must be carried out in a fair and expert manner.

Contract Negotiation and Award. After the highest-ranking vendor is selected, further negotiations must be carried out leading to and including development of an executable contract.

Implementation Project Management. One-time project management assistance should be outsourced. Tasks would include vendor performance oversight, technical advisory services to DOC and the NEVCOM Board, project tracking, and acceptance testing oversight.

> Benefits of Recommendation 9: By outsourcing the majority of implementation tasks, under the oversight and supervision of DOC and the NEVCOM Board, the State can ensure adequate project management from contractor selection through system acceptance without adding permanent staff.

10. Develop Life Cycle Funding Approach

The state should, based on the information in this Plan, explore all its options for funding and funding sources, and develop a life cycle funding strategy that takes total system costs into consideration and creates equitable and stable methods for sharing costs among system participants. Issues implied by this recommendation and covered in more detail in Section 6 include the following:

- Sources of state and local funding,
- Delineation of user and common system cost elements,
- Initial implementation costs and ongoing lifecycle factors such as maintenance, operating, staffing and replacement costs,
- Use of distributed payment mechanisms, and
- Availability and qualifications for Federal grant funding and asset sharing.

> Benefits of Recommendation 10: Sufficient levels of funding and appropriate distribution of costs for major public safety infrastructure improvement over the life of the system.